



# Recent Improvements on AIRS V6-CH4 retrieval, validation and data analysis

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*Thomas.S.Pagano(JPL), Leonid Yurganov(UMBC)*

**Thanks all AIRS team since a good retrieval of CH4 relies on a good retrieval of Temp and Wv**

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**NASA Sounder Science Team Meeting  
Nov. 9, 2011, Greenbelt, MD**

# Outline

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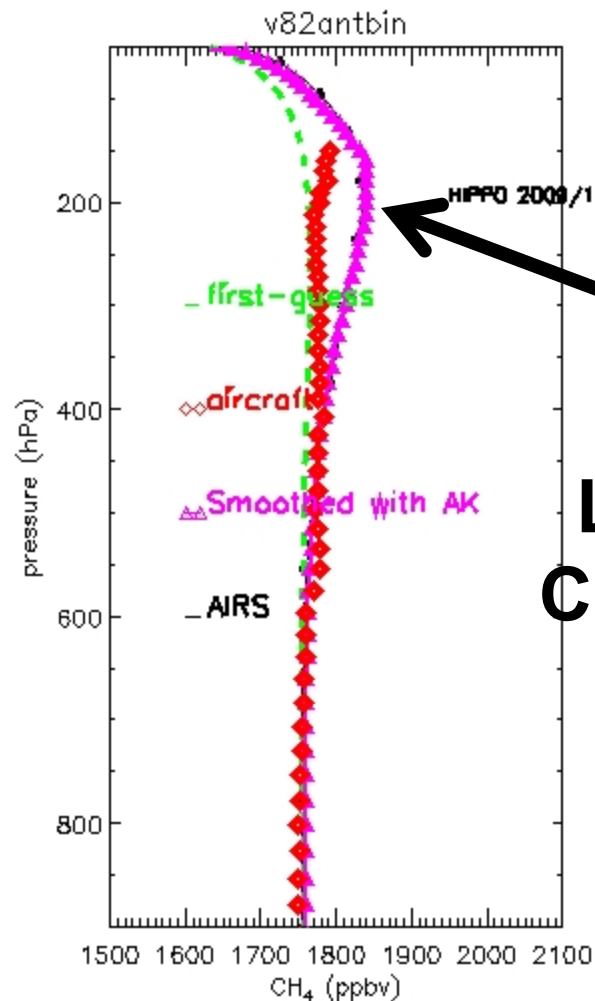
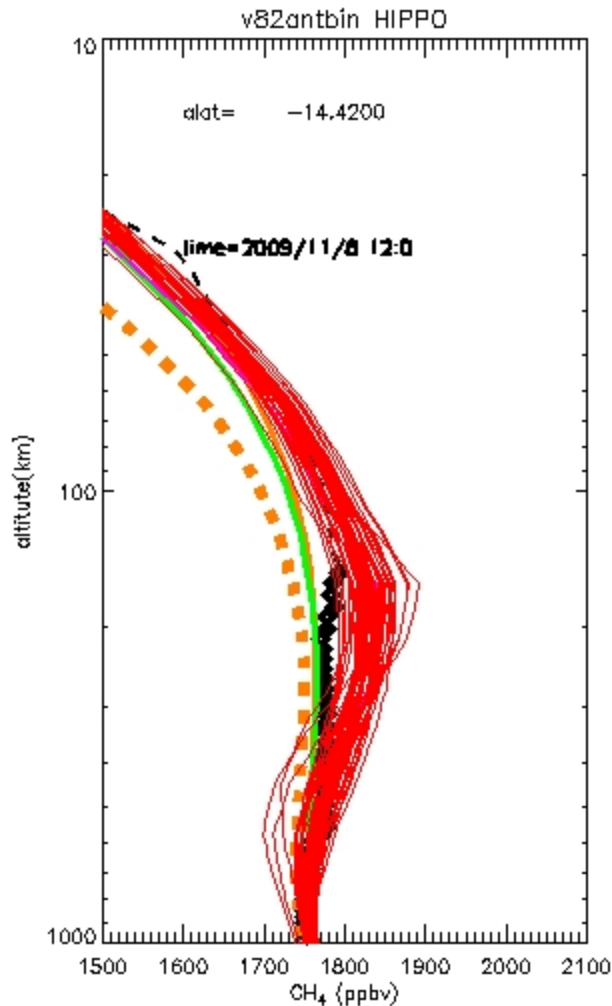
- **Recent Improvements for Version 6**
  - 1) Based on intensive validation using aircraft measurements (esp. HIPPO);**
  - 2) Through comparison with Optimal-Estimation method(not shown);**
  
- **Recent Scientific Activities:**
  - with a focus on CH<sub>4</sub> in the HNH and recent trend study**

# Optimization in AIRS V6 – CH<sub>4</sub>

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- **Optimization of first-guess**
  - **Add 3 trapezoid functions (from 7 to 10)**
  - **Channels & damping (adjust accordingly)**
  - **Uncertainty of Spectroscopy in CH<sub>4</sub> band and forward model are two major factors impacting CH<sub>4</sub> retrieval**
- 1) V5 - a rough tuning to the absorption in CH<sub>4</sub> peak channels by 2%
  - 2) V6 – a more careful tuning to CH<sub>4</sub> channels by 1%-1.5% (not just peak)

# A tropical case → tuning is required



Large increase of  
CH<sub>4</sub> with altitude in  
tropics ?

Retrieved CH<sub>4</sub> (@200 hPa) is obviously  
larger than observation and forms a bump

# AIRS V5→ V6

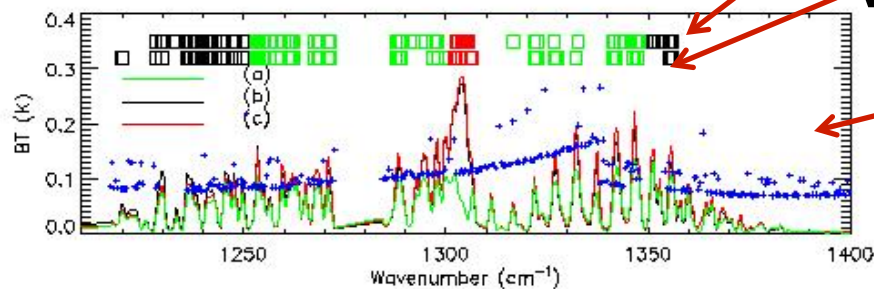
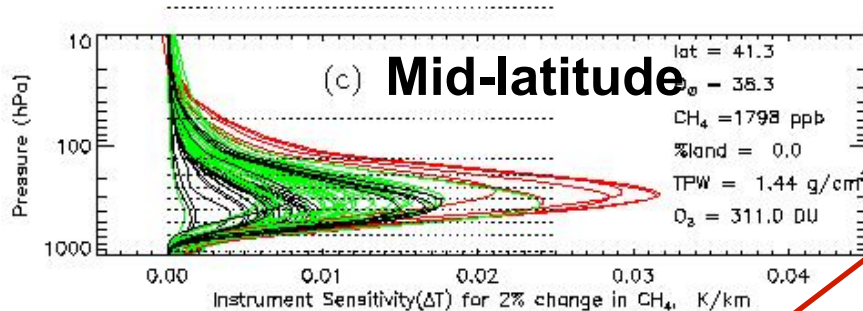
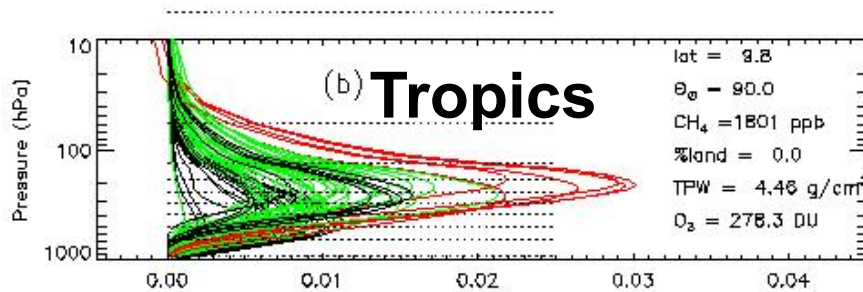
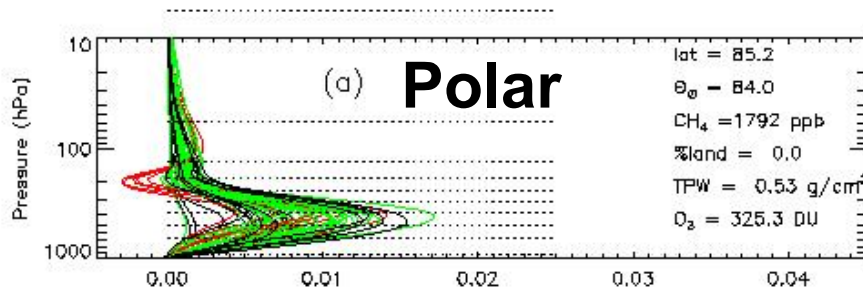
- 7 retrieval layers (V5)  
--> 10 (V6)

- New channel selection

V5

V6

- Able to resolve 2% change of CH<sub>4</sub>

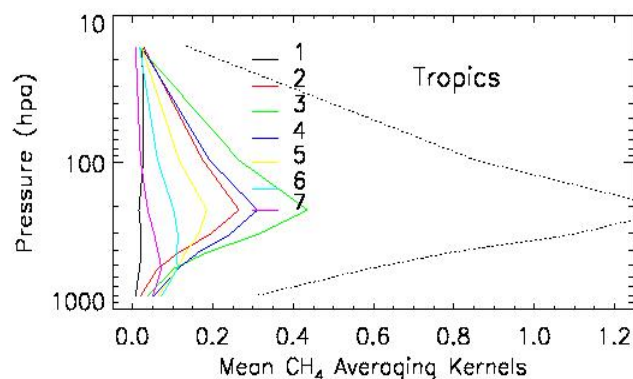
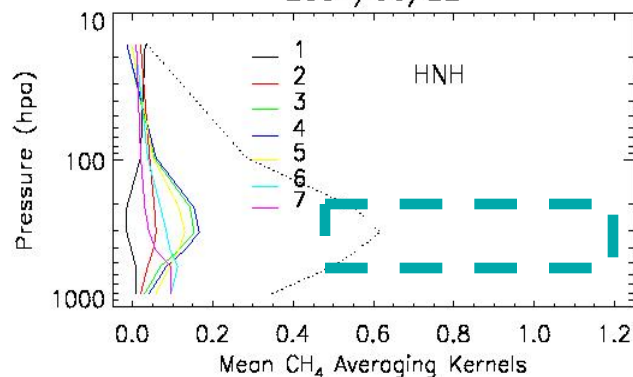


# V6 has more sensitivity to lower tropospheric CH<sub>4</sub>

## Averaging kernels

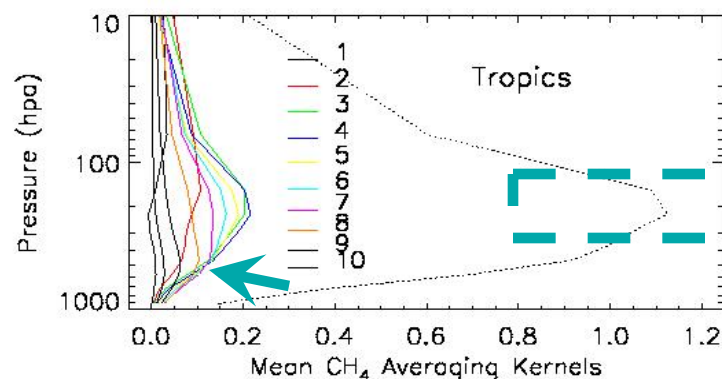
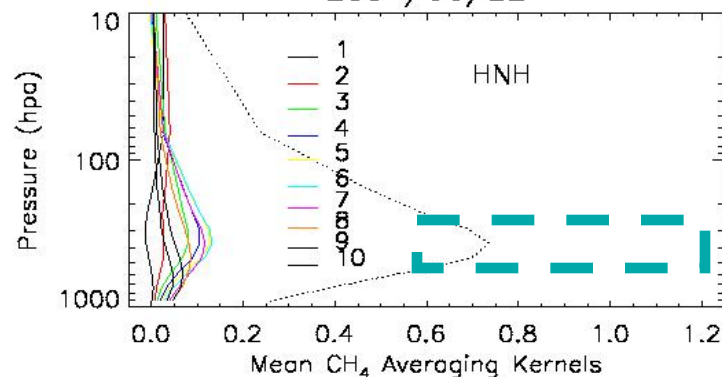
### V5

2004/06/22



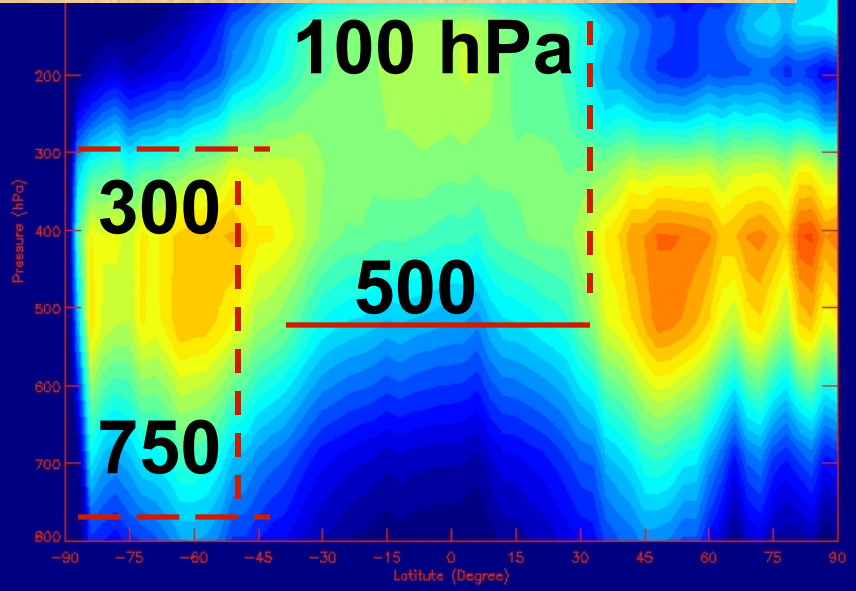
### V6

2004/06/22

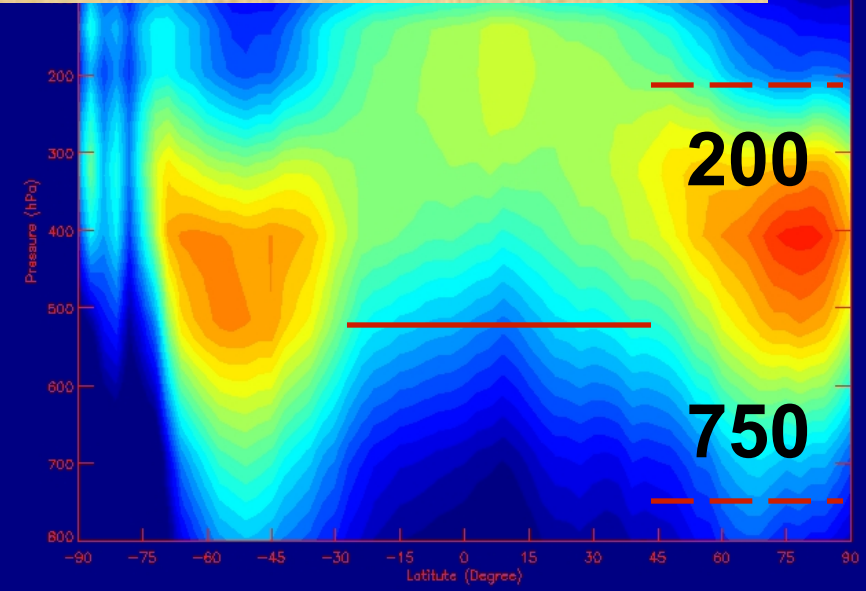




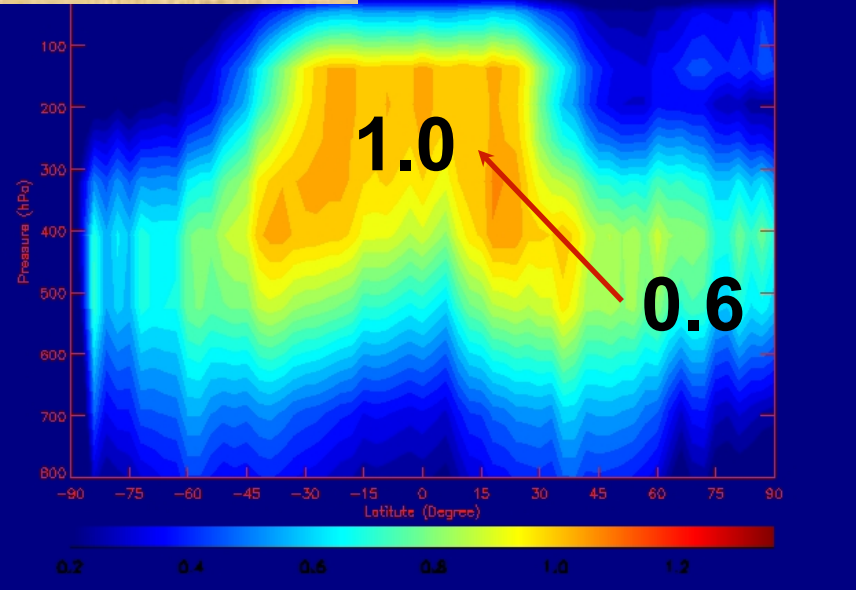
2009/1/10, normalized



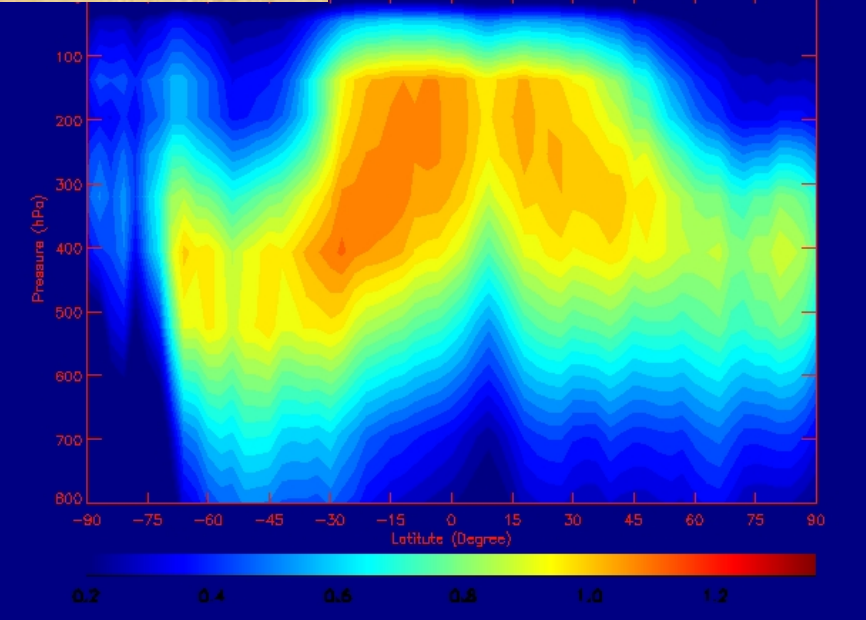
2005/8/5, normalized



2009/1/10



2005/8/5



Sensitivity of AIRS CH4(V6)

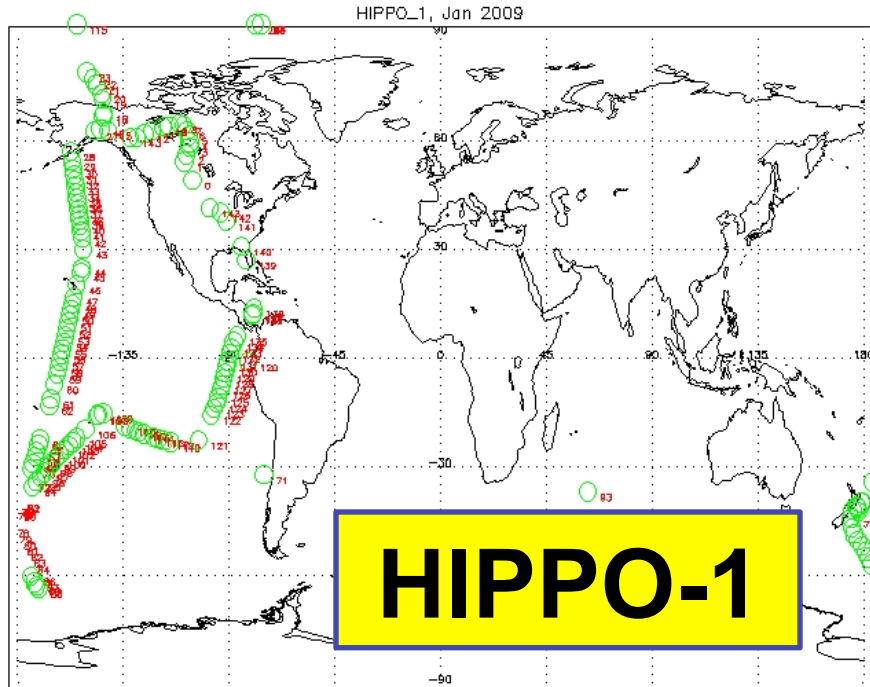
# **All these improvements in V6 are based on extensive validation**

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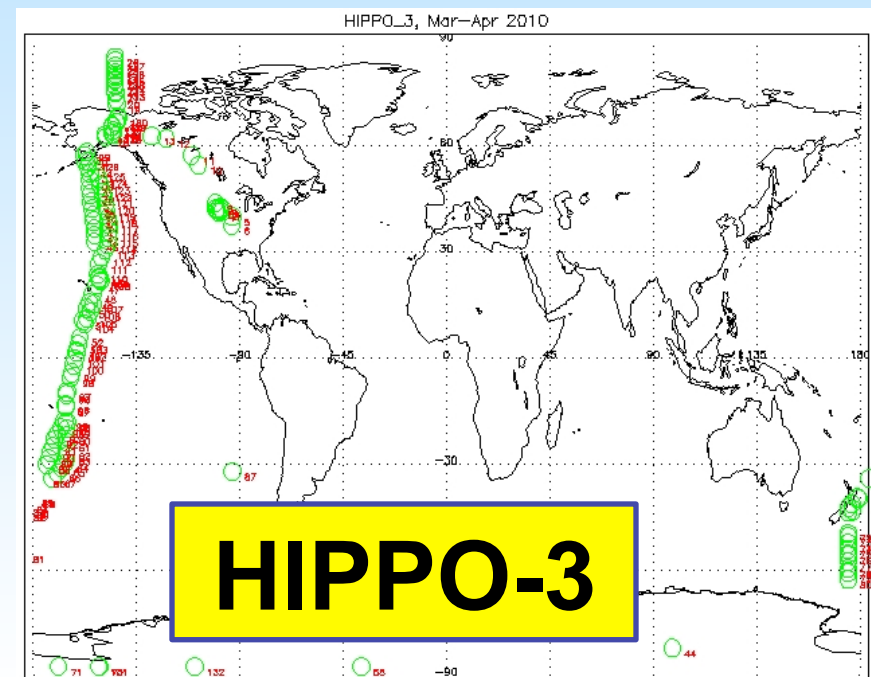
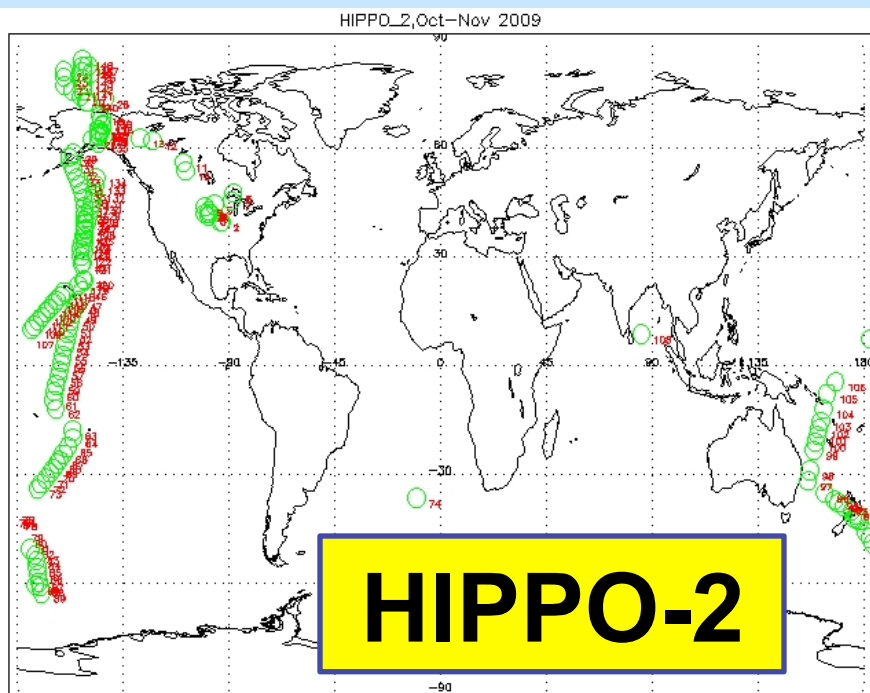
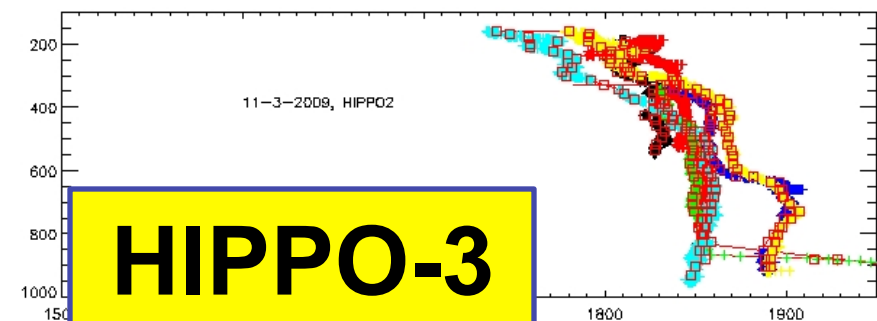
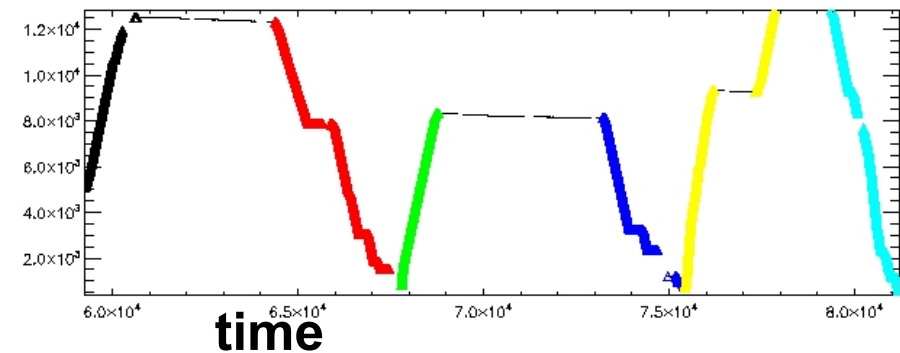
Aircraft measurements used include

1. Aircrafts measurements from NOAA/ESRL/GMD  
(the only one used for V5 optimization)
2. Intex-A (2004), -B(2006)
3. START08(2008)
4. ARCTAS(2008)
5. HIPPO-1, -2(2009), -3(2010)  
HIPPO-4, -5 data have not been released to public





PO



343-496 hPa(pge52bin) hippo

$R = 0.87(0.92)$

$N = 103$

Bias =  $-0.21(-1.13)\%$

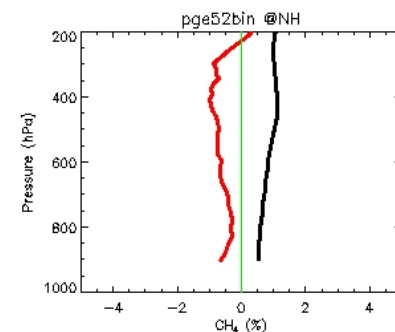
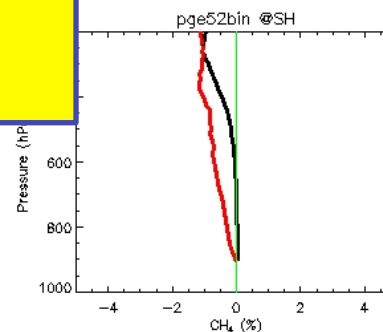
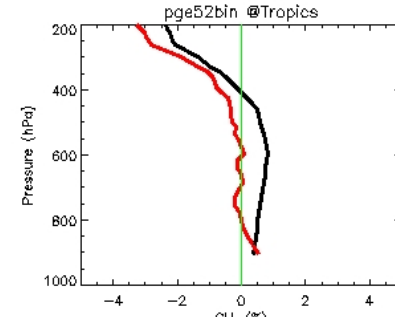
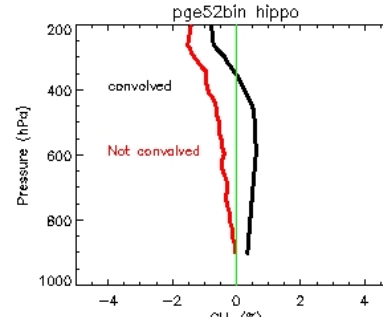
rms =  $1.31(1.47)\%$

Convolved with AK

Truth

?

V5



343-496 hPa(v82antbin) hippo

$R = 0.91(0.88)$

$N = 104$

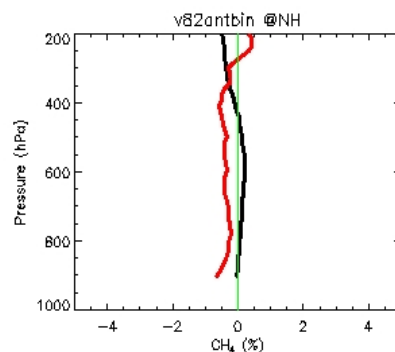
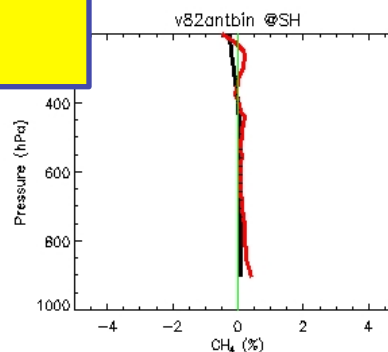
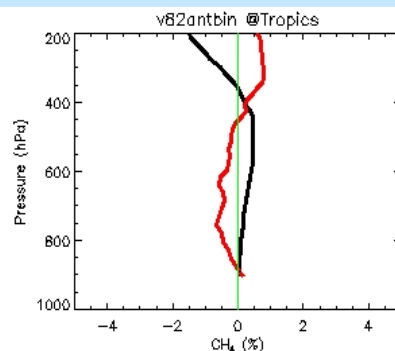
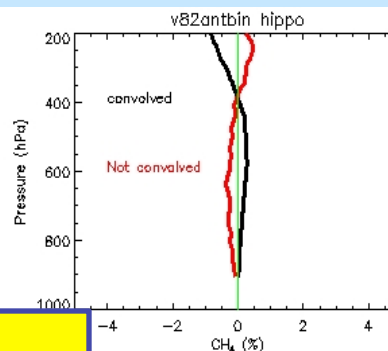
Bias =  $-0.26(0.200)\%$

rms =  $1.02(1.17)\%$

Convolved with AK

Truth

V6

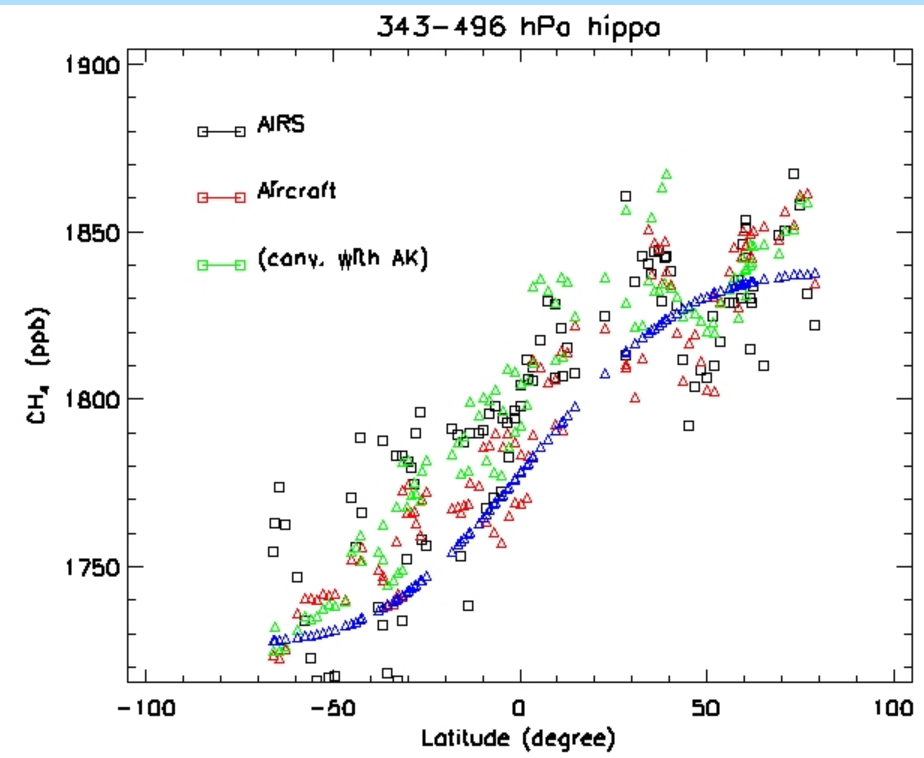
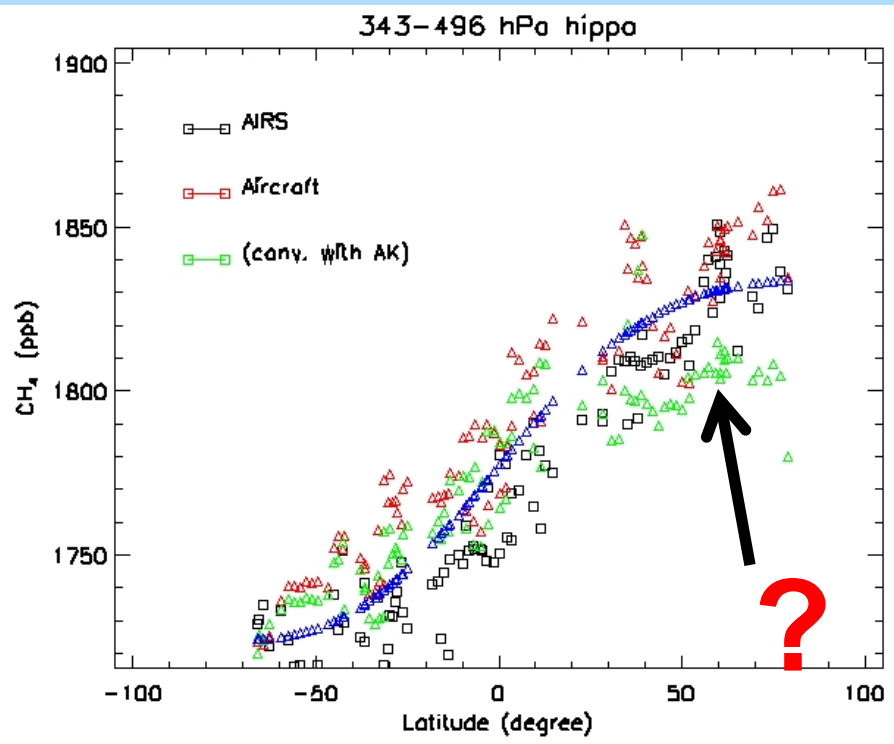




# Comparison of Latitudinal Gradient (343-493 hPa) in V5, V6 (HIPPO-1, 2009/01)

**V5**

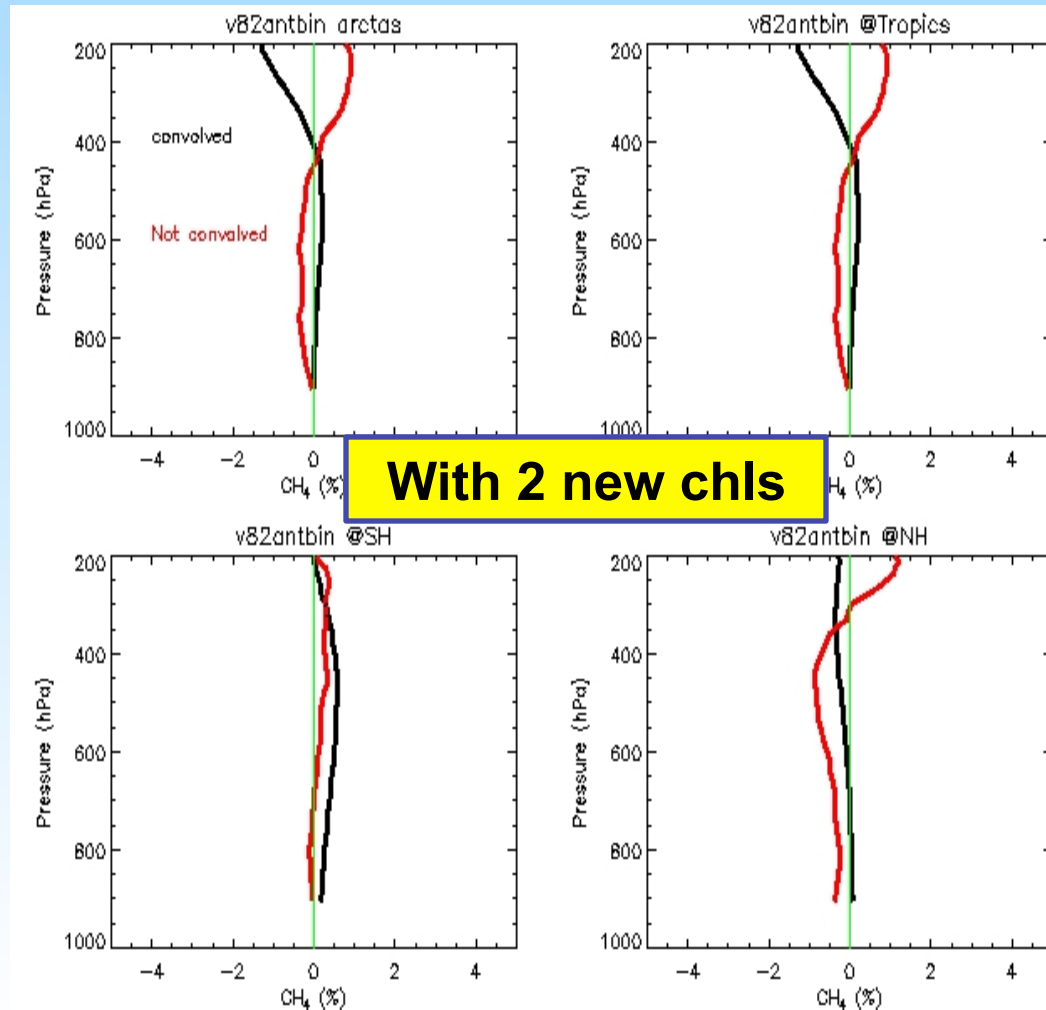
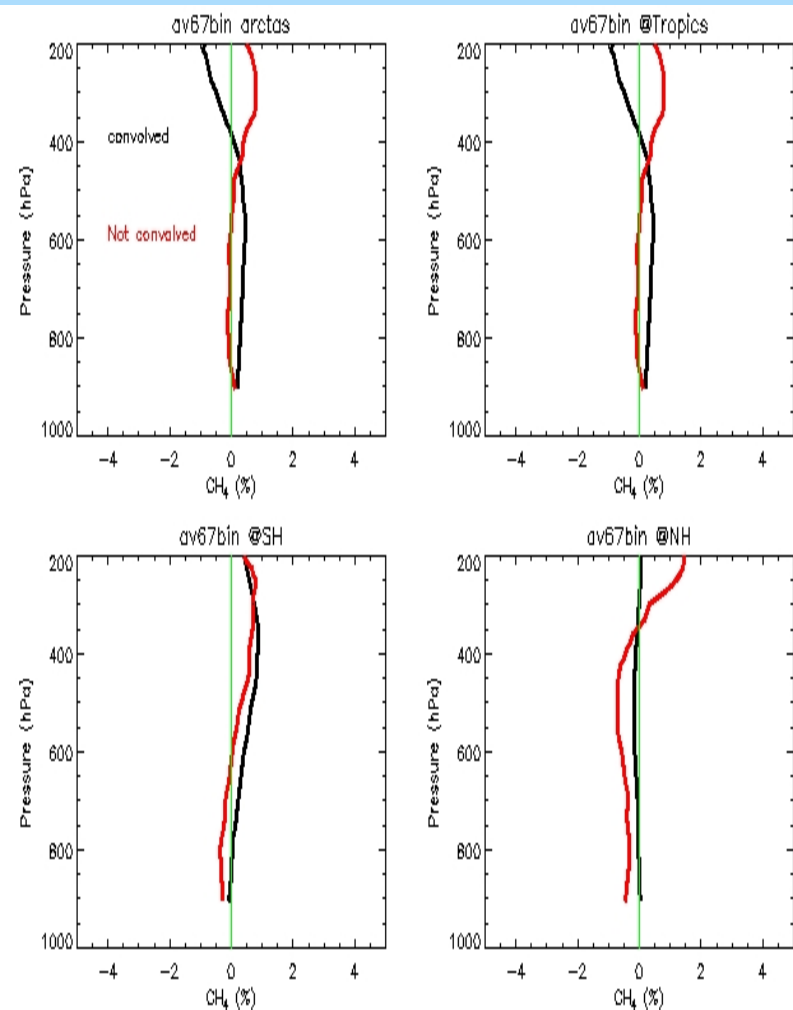
**V6**



**Current tuning was mainly based on HIPPO-1 data**

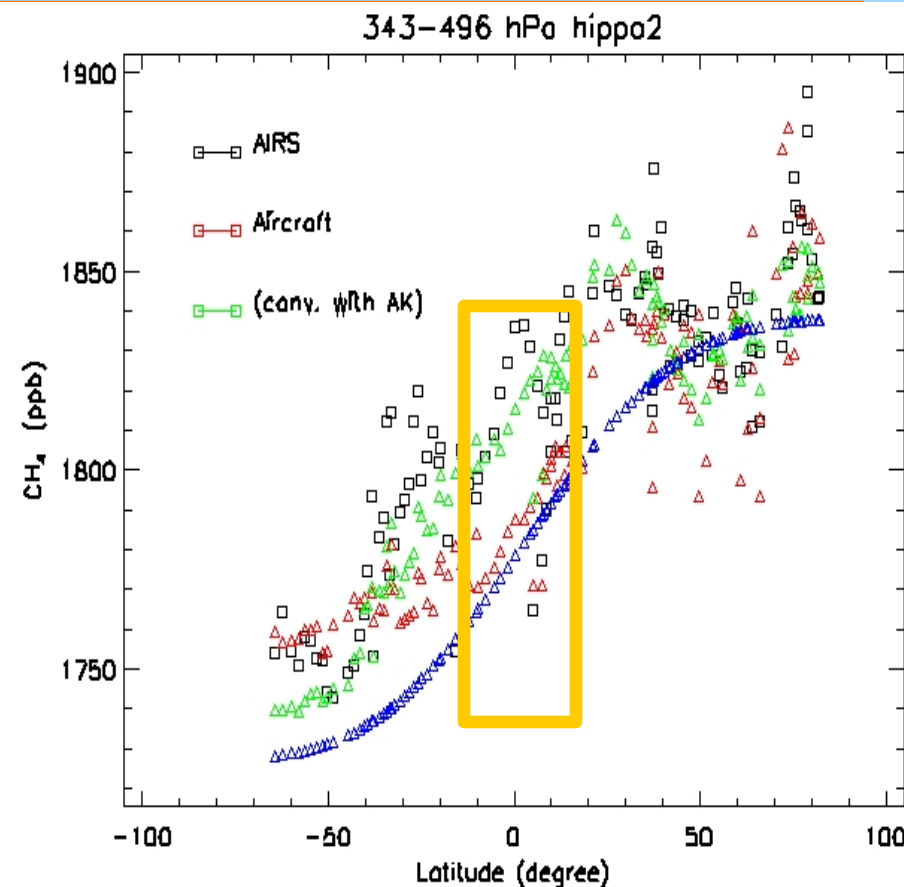
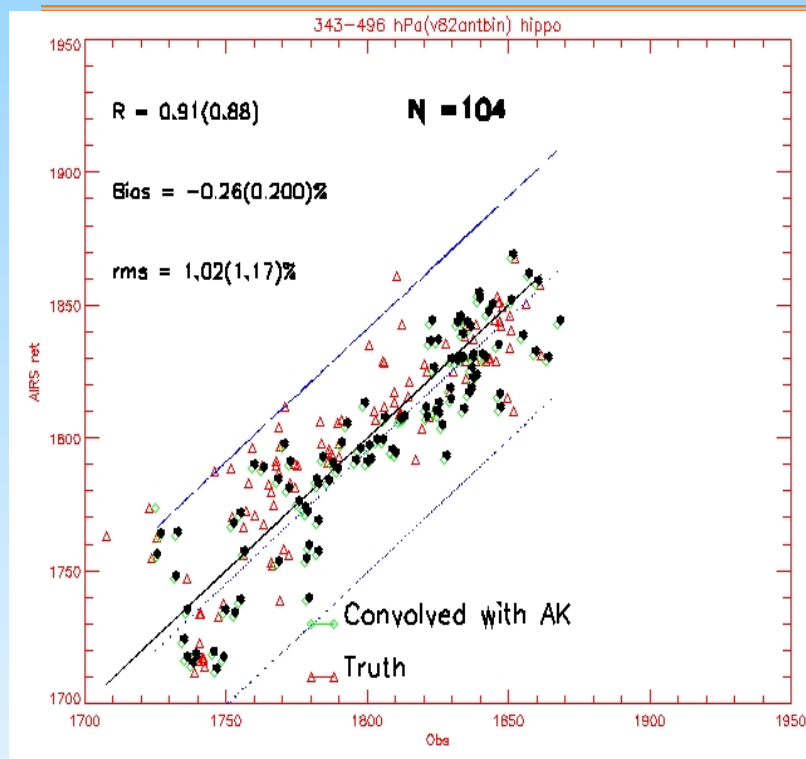
# Maybe better to add two more channels in V6, but need more check using HIPPO-2,-3,-4,-5 data

In the past 1 month, we focus on the tuning and validation using more aircraft data from Prof. Steven Wofsy (Harvard Univ.); We took back two channels near the Q-branch, and the results are *slightly better*.



# Validation of CH<sub>4</sub>-V6

# HIPPO-2

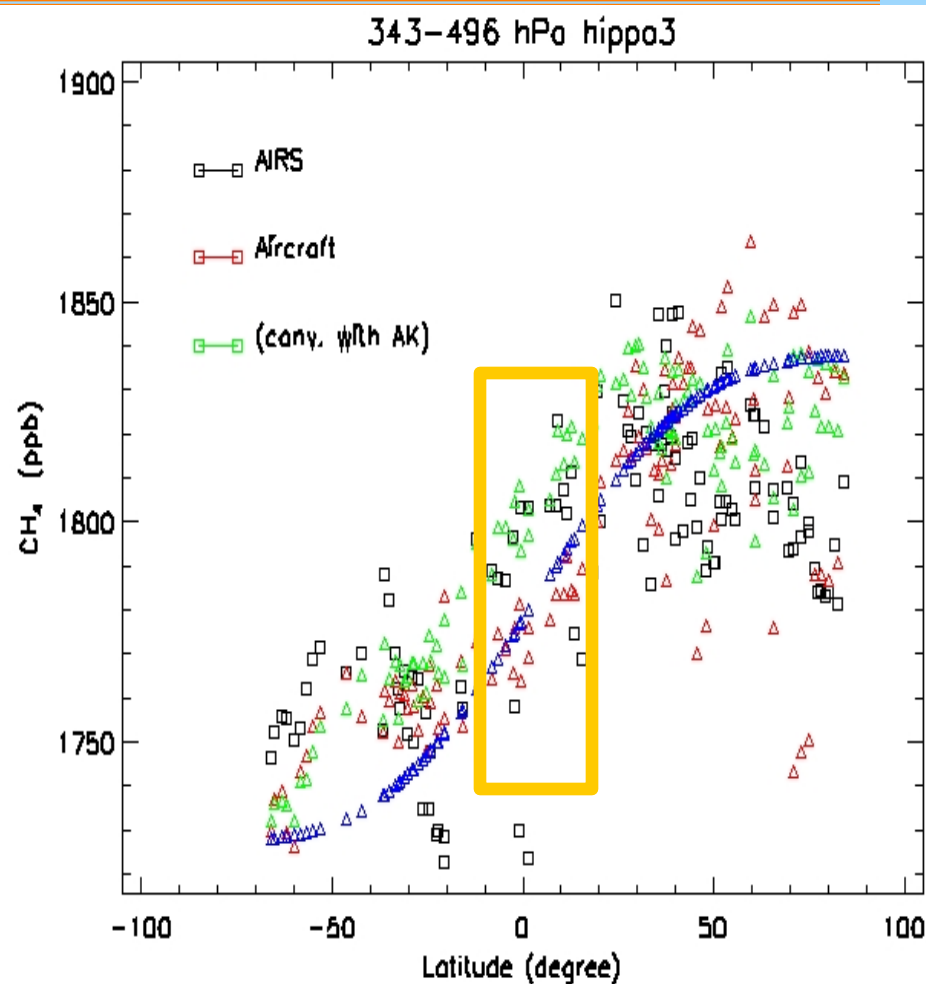
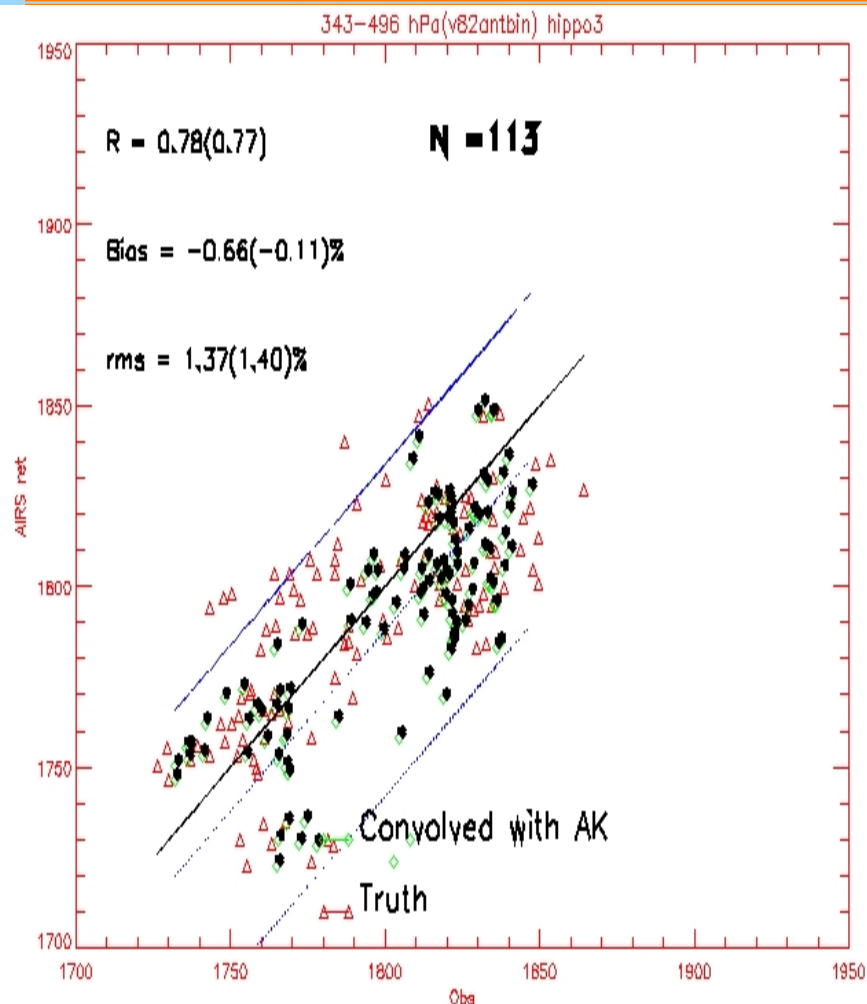


2009/10, 2009/11

In tropics, AIRS-CH<sub>4</sub> is higher than in-situ observation, but agree with obs-convolved with AK

# Validation of CH<sub>4</sub> V6

## HIPPO-3



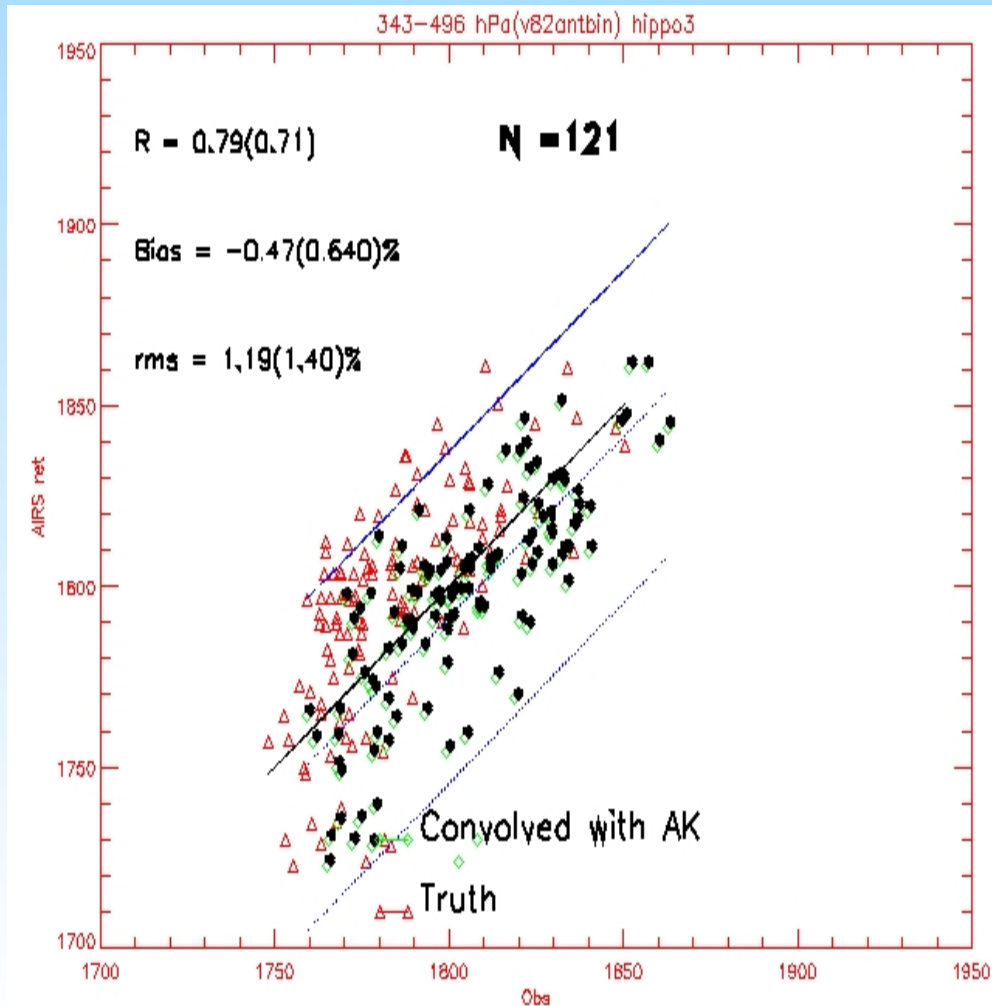
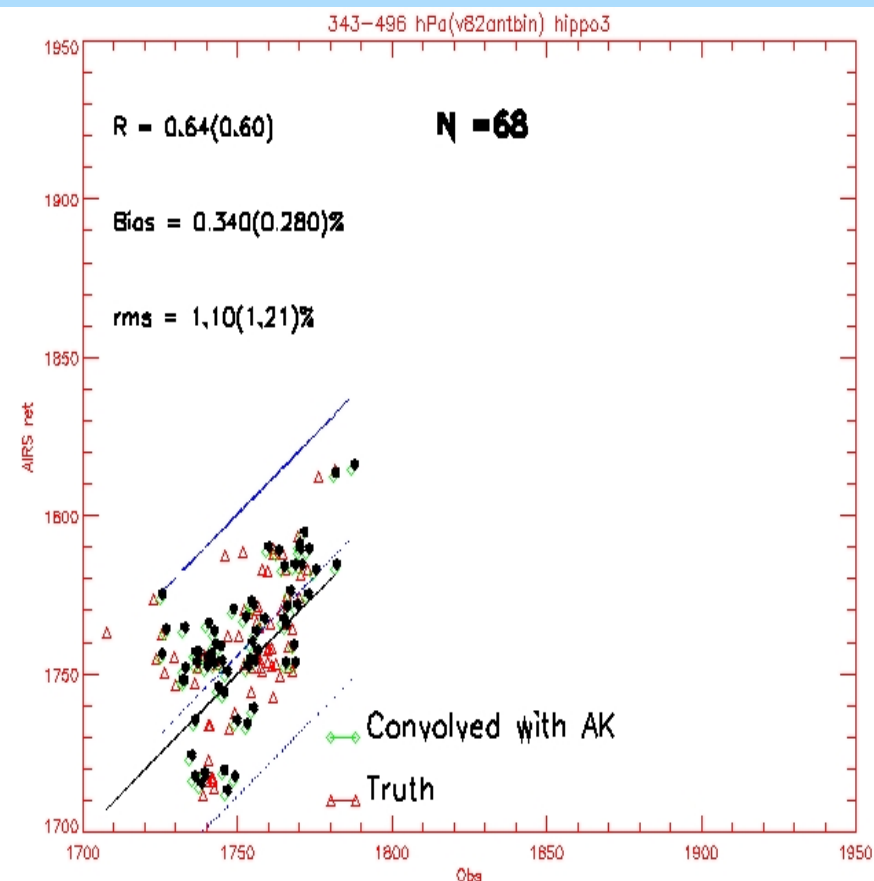
2010/03, 2010/04



# Validation in V6 (using HIPPO-1,-2,-3)

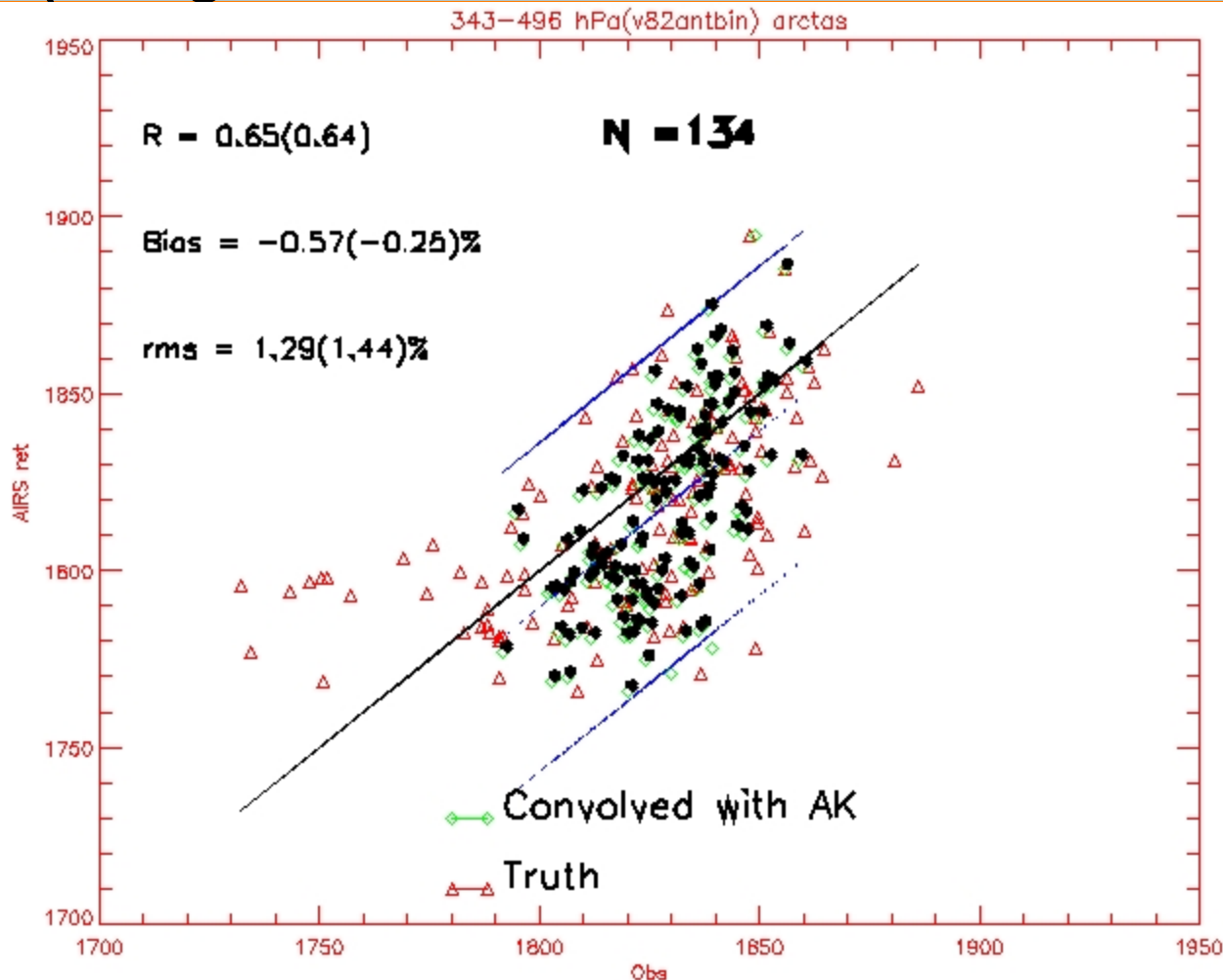
**90-30 °S**

**30S to 30 °N**



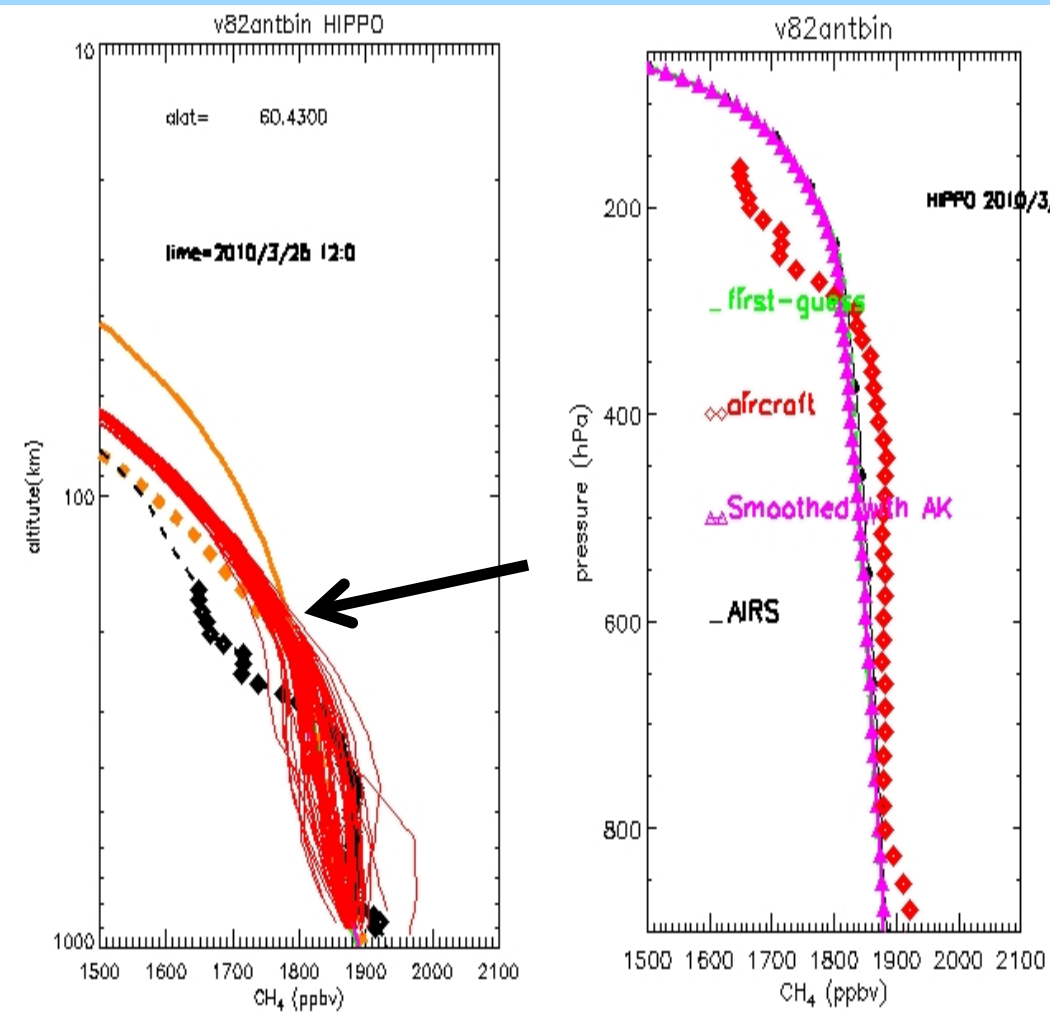
# HNH (55N-90N)

(using ARCTAS, Intex-A,-B, HIPPO-1,2,3)



Due to the lower information content, correlation  
in high latitude is smaller than in tropics

# Any more problems ?



**During stratosphere intrusion in the HNH, retrieval has a larger bias**

One possible way to fix this problem is to modify the firstguess according to the tropopause height – need more investigation → V7

# Recent Scientific activities since last Meeting

## → promote the use of AIRS CH<sub>4</sub> products

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1. **IWGGMS-7**, May 16, 2011, Edinburgh, UK (**no money to travel, presented by Tom Pagano, and missed the GOSAT PI meeting followed IWGGMS-7**).
2. In close contact with GOSAT team and plan to co-author a paper on the comparison of AIRS CH<sub>4</sub> and GOSAT-CH<sub>4</sub> product.
3. One Ph.D thesis in Purdue University to assimilate AIRS CH<sub>4</sub> data in model simulation and a paper is in preparation (just graduated) and NOAA/ESRL expressed their interest to assimilate AIRS CH<sub>4</sub> in CarbonTracker model.
4. Leonid and myself are in closely contact with Prof. Steven Wofsy (Harvard Univ.) , who is very interested in comparing AIRS CH<sub>4</sub> with HIPPO measurements → Comparison using V5 data is promising and looking forward to V6 data.
5. K. Walter in UAF has one project about Arctic CH<sub>4</sub> study granted by NASA (ROSE) in 2010, AIRS CH<sub>4</sub> data was proposed to use (we are a unfunded collaborator).
6. Leonid gave a presentation at Arctic Methane Workshop, London, 15 Oct. 2011.
7. Paper (by Xiong et al. ) was just accepted in the proceeding of 10<sup>th</sup> International Conference on Permafrost (June 2012, **still have not found travel money**).

# Thermal Infrared Sounder, like AIRS and IASI, CrIS are pretty valuable in space-borne observation of CH<sub>4</sub> in the polar regions as:

- ARCTIC is a huge “carbon” pool and vulnerable to climate warming
- Space-borne measurement by NIR is not efficient in the polar region
- Lidar observation from space is promising but still under development

Mid-upper tropospheric methane in the high Northern Hemisphere: Spaceborne observations by AIRS, aircraft measurements, and model simulations - Mozilla Firefox

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JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, D19309, 15 PP., 2010  
doi:10.1029/2009JD013796

**Mid-upper tropospheric methane in the high Northern Hemisphere: Spaceborne observations by AIRS, aircraft measurements, and model simulations**

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Center for Satellite Applications and Research, National Environmental Satellite, Data, and Information Service, NOAA, Camp Springs, Maryland, USA

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CGER, National Institute for Environmental Studies, Tsukuba, Japan

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Global Monitoring Division, ESRL, NOAA, Boulder, Colorado, USA

Prabir K. Patra  
Research Institute for Global Change, JAMSTEC, Yokohama, Japan

Spaceborne measurements by the Atmospheric Infrared Sounder (AIRS) on the EOS/Aqua satellite provide a global view of the methane (CH<sub>4</sub>) distribution in the mid-upper troposphere (MUT-CH<sub>4</sub>). The focus of this study is to examine the spatiotemporal variation of MUT-CH<sub>4</sub> in the high Northern Hemisphere (HNH) using AIRS retrievals, aircraft measurements, and simulations from a forward chemistry-transport model (i.e., ACTM). Data from 2004 and 2005 focusing over two regions (Alaska and Siberia) are analyzed. An important feature in the seasonal variation of CH<sub>4</sub> we found is the summer increase of MUT-CH<sub>4</sub>, which is nearly opposite to the summer minimum of CH<sub>4</sub> in the marine boundary layer (MBL). This study also demonstrated an apparent increase of CH<sub>4</sub> over

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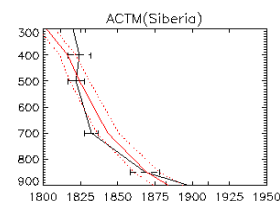
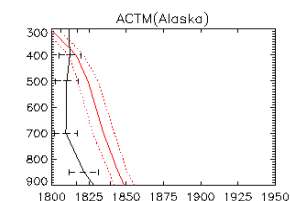
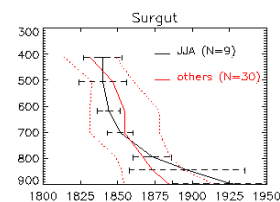
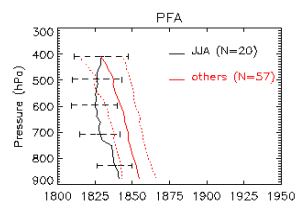
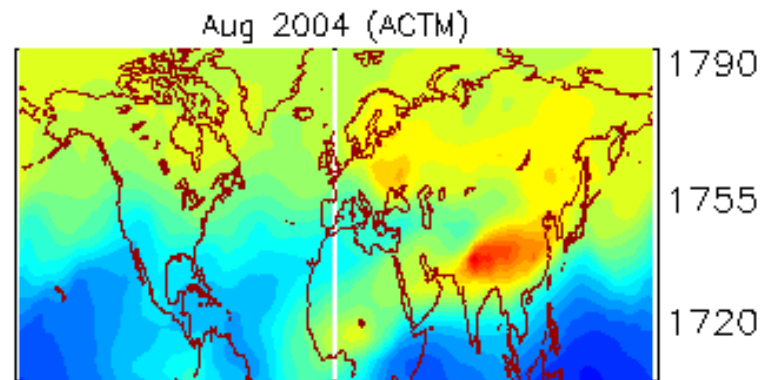
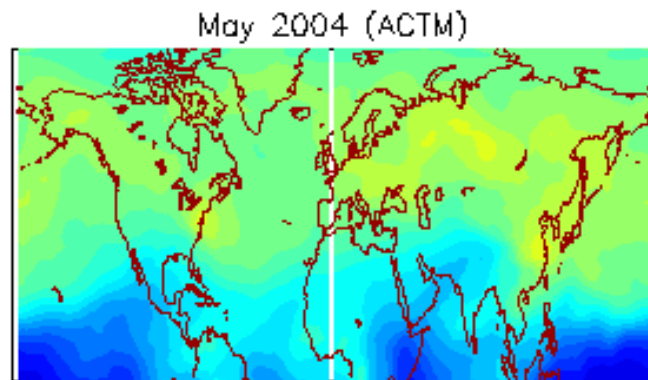
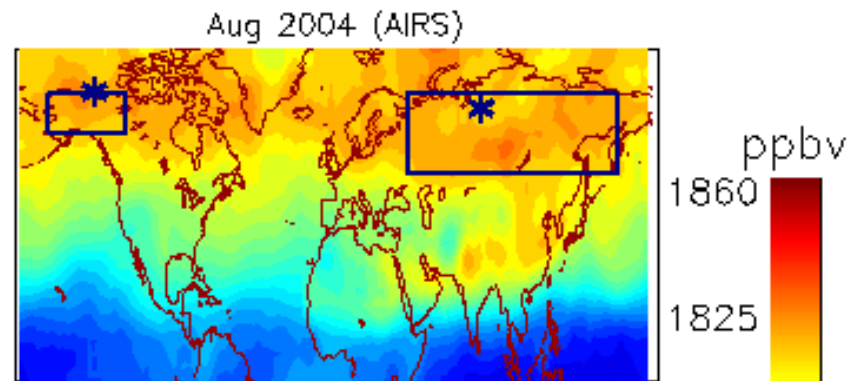
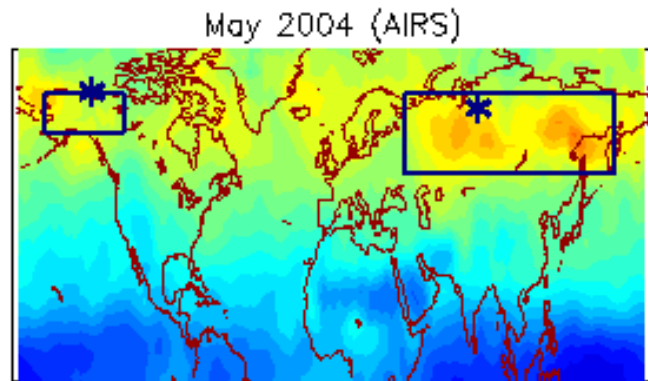
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methane  
atmosphere  
AIRS

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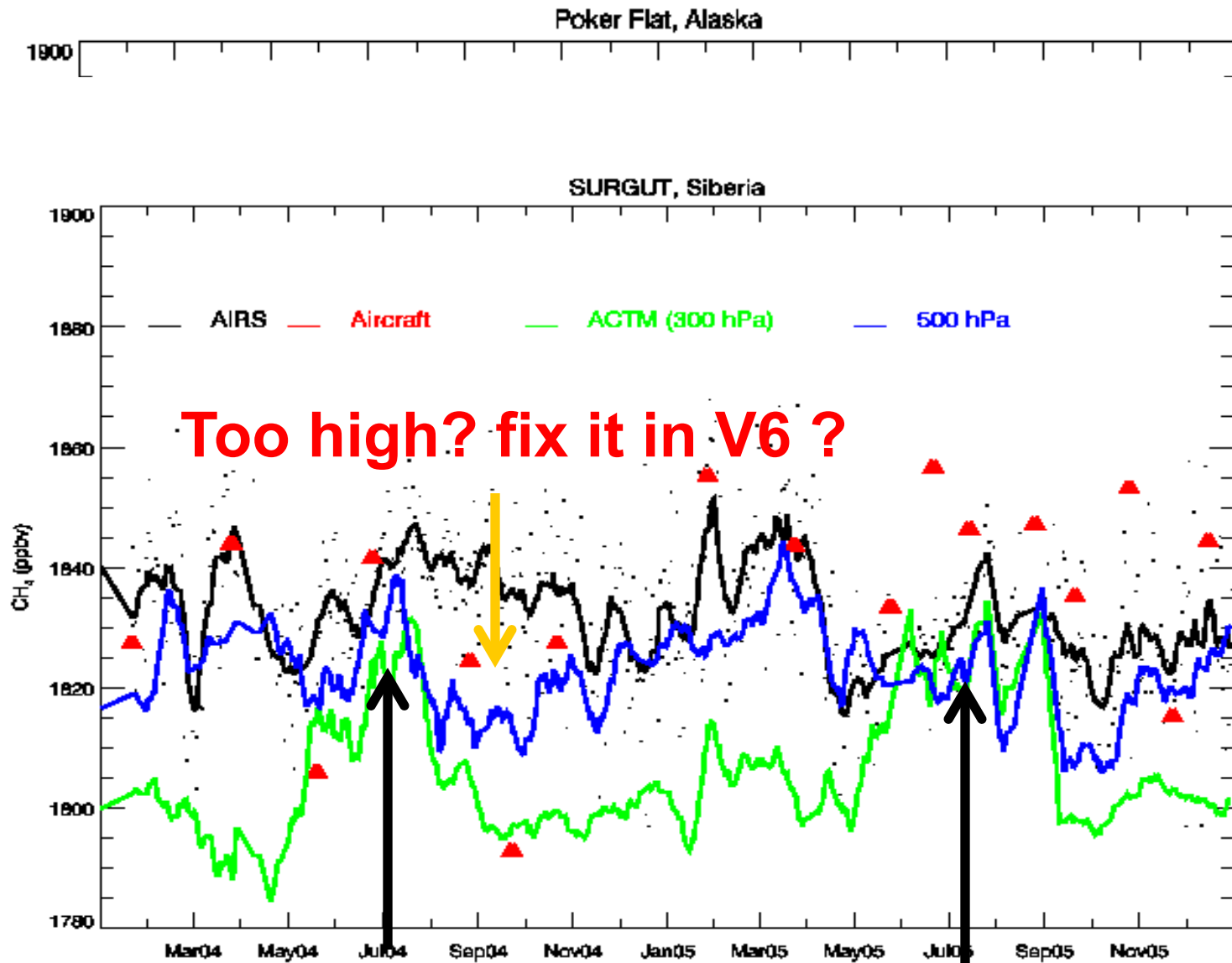
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start Mid-upper tropospher... Inbox - Mozilla Thund... Microsoft PowerPoint ... 9:39 AM



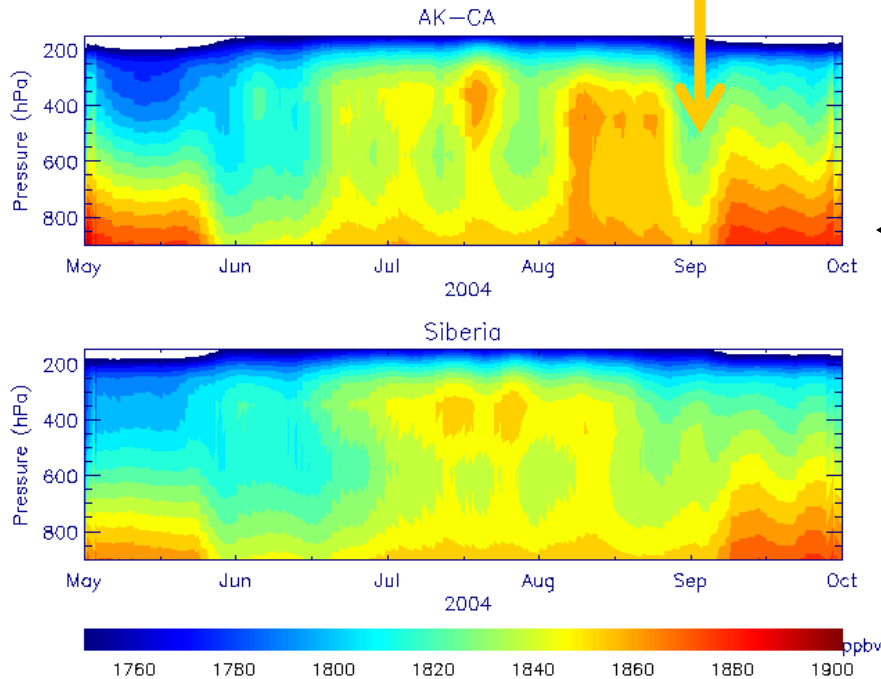
•Xiong, X., Barnet, C.; Zhuang, Q.; Machida, T.; Sweeney, C.; Patra, P.K., 2010, Mid-upper Tropospheric Methane in the High Northern Hemisphere: Space-borne Observations by AIRS, Aircraft Measurements and Model Simulations, *J. Geophys. Res.*, 115, D19309, doi:10.1029/2009JD013796.





High CH<sub>4</sub> in summer

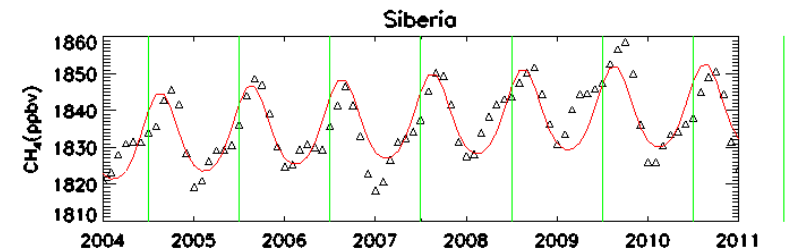
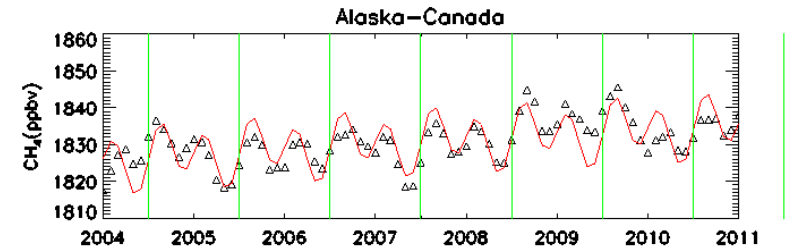
Summer of 2004,  
from “V6” (NOAA)



more features in  
lower troposphere

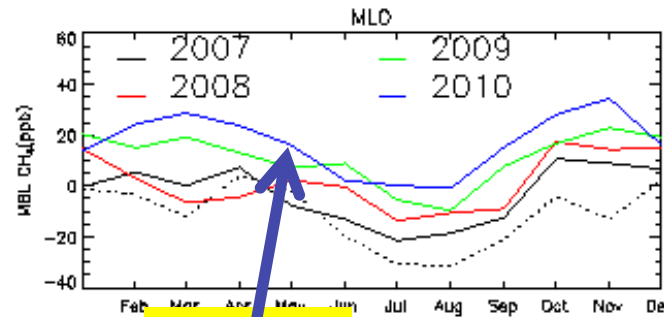
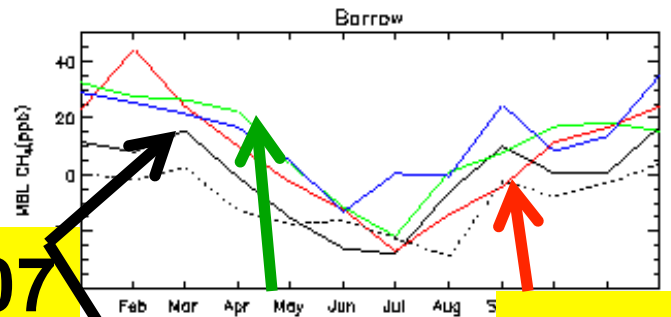
From May to Sept, 2004

Xiong, X., T. Zhang, E. Maddy, Q. Zhuang, C.D. Barnet, Atmospheric Methane in the High Northern Hemisphere and its Relation with Permafrost *Proceedings of the Tenth International Conference on Permafrost*, Russia, 2012 (accept).

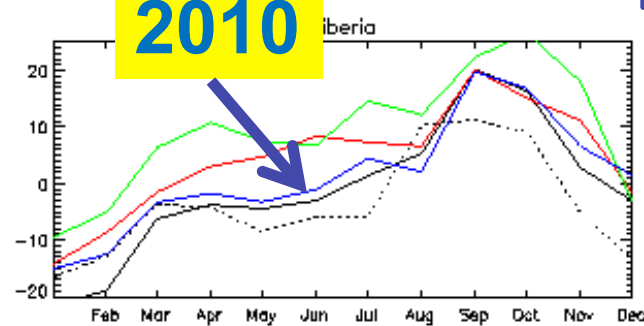
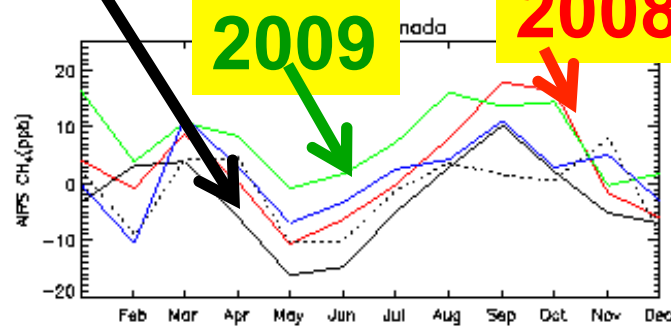


significant increase of CH<sub>4</sub> occurs in  
2008 and 2009

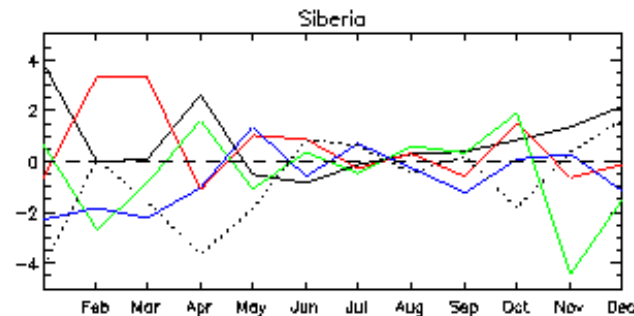
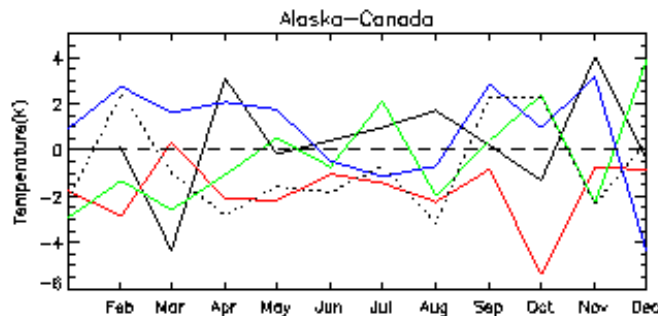
# CH<sub>4</sub> anomaly from 2006 to 2010



**MBL,**  
increase from  
2007 to  
2009/2010



**AIRS**  
increase from  
2008 to 2009

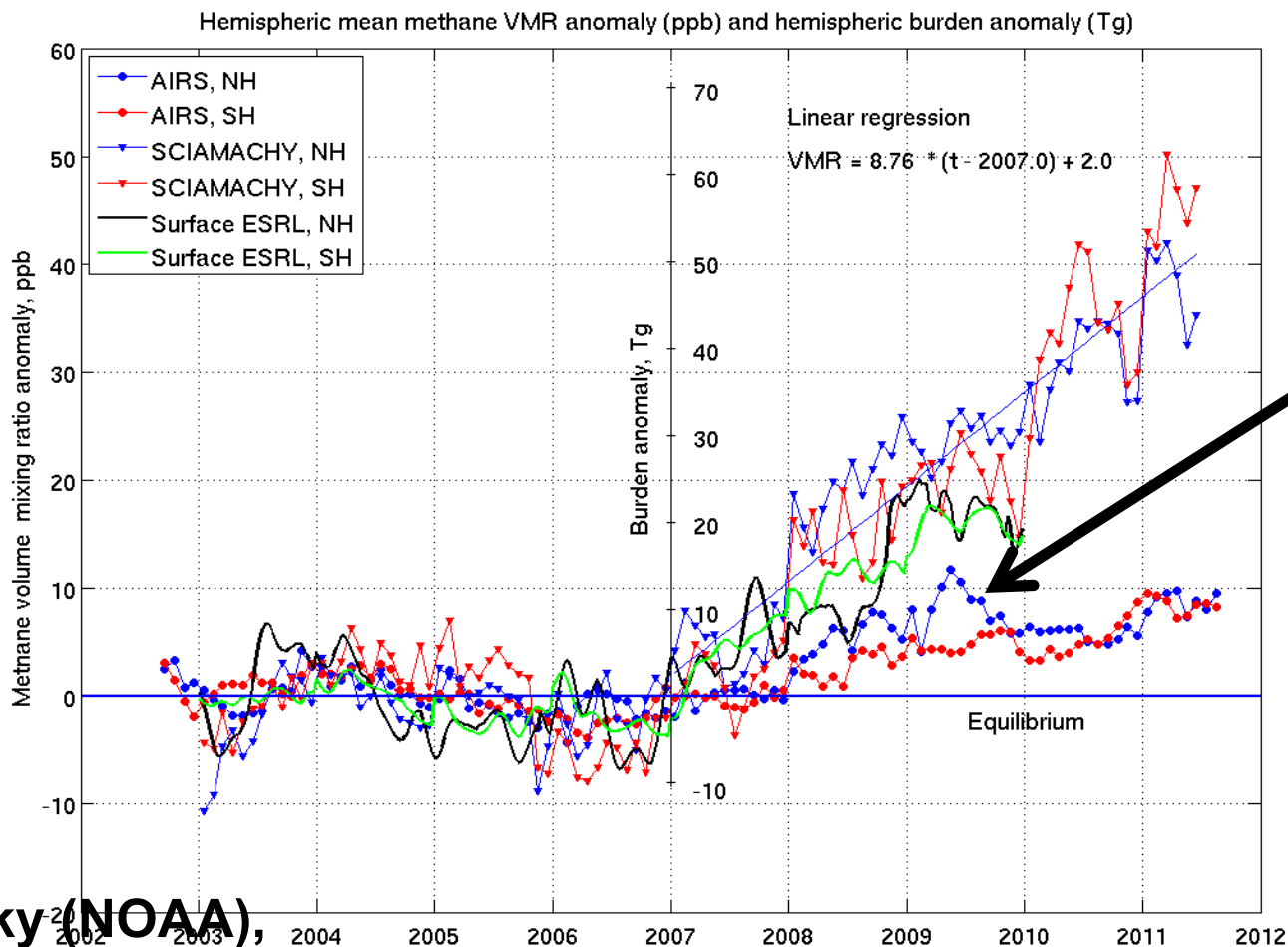


**Ts warm**  
summer in  
2007, AK

significant increase of CH<sub>4</sub> occurred in 2008 and 2009 (AIRS)  
Increase of surface CH<sub>4</sub> started in 2007, continued in 2008-2009, even  
in 2010 in tropics



**Satellite- and surface-based anomalies of CH<sub>4</sub> in ppb (left scale) and in Tg of CH<sub>4</sub> (right scale) for troposphere of each hemisphere. Reference period between 2003 and 2007. Global burden anomaly is the sum of Northern and Southern anomalies.**



Courtesy  
Ed Dlugokencky (NOAA),  
Christian Frankenberg (JPL),  
Remco Scheepmaker (SRON)

**Arctic Methane Workshop, London,  
15 October 2011, Leonid Yurganov et al.**

# Summary

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- 1. Improvement in V6-CH<sub>4</sub> have been made under extensive validations. It has better sensitivity to a lower tropospheric CH<sub>4</sub> than V5, i.e. 200-500 hPa in tropics and 300-750 hPa in polar, and better accuracy (<1.5%);**
- 2. The recent CH<sub>4</sub> increase since 2007 is observed from AIRS measurement, however the significant increase occurs in 2008, 2009 – one year delay than surface CH<sub>4</sub>.**
- 3. Our studies highlight the value to use TIR to measure CH<sub>4</sub> over HNH, in which the emission from wetland and thawing permafrost are large but other observations (NIR from space and ground-based) are difficult.**

# Acknowledgement

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- **Thanks to Steven C. Wofsy (Harvard University) and HIPPO team to provide HIPPO data;**
- **Also thanks the teams of INTEx-A, –B; START08; ARCTAS for sharing their aircraft measurements.**



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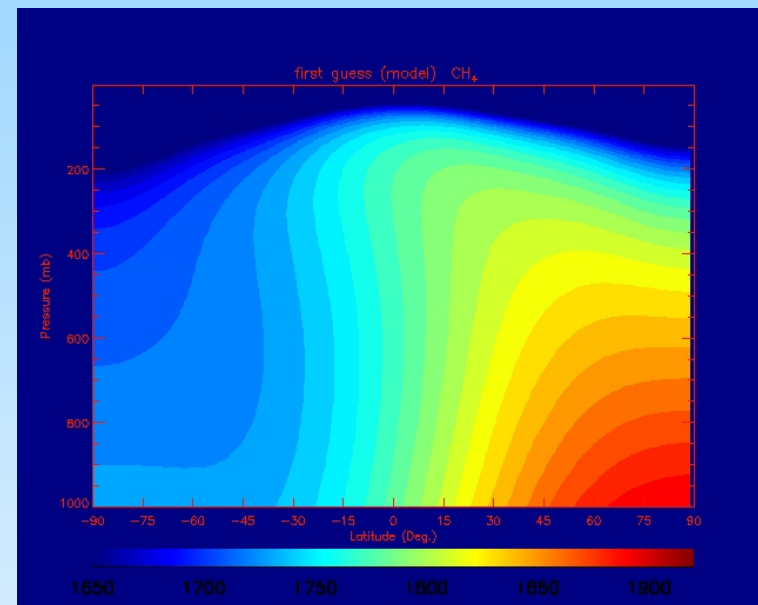
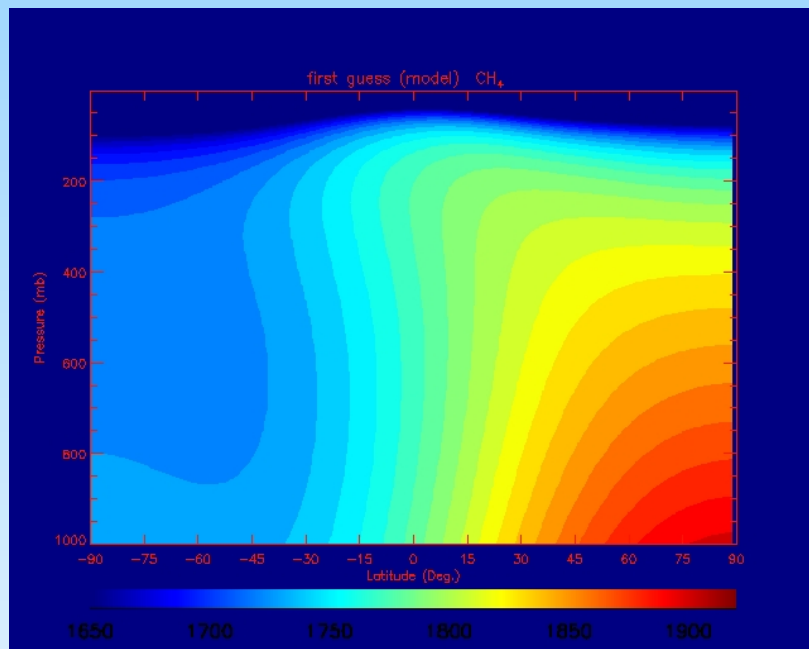
**We tried hard and are almost volunteering to improve AIRS V6-CH<sub>4</sub> retrieval and validation, and promote the use of AIRS CH<sub>4</sub> products (pretty well accepted!), but are facing a problem of no-funding support.**

# Acronym

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- **INTEX** Intercontinental Chemical Transport Experiment: The first phase (INTEX-A) was completed in the summer of 2004 and the second phase (INTEX-B) was performed in the spring of 2006.
- **HIPPO**: HIAPER Pole-to-Pole Observations of Carbon Cycle Greenhouse Gases study (phase 1 --Jan 2009).
- **START08 (Pre-HIPPO)** : Stratosphere-Troposphere Analyses of Regional Transport (1 April to 16 May and 16 to 28 June, 2008).
- **ARCTAS** (Arctic Research of the Composition of the Troposphere from Aircraft and Satellites): March, April, June, and July, 2008.

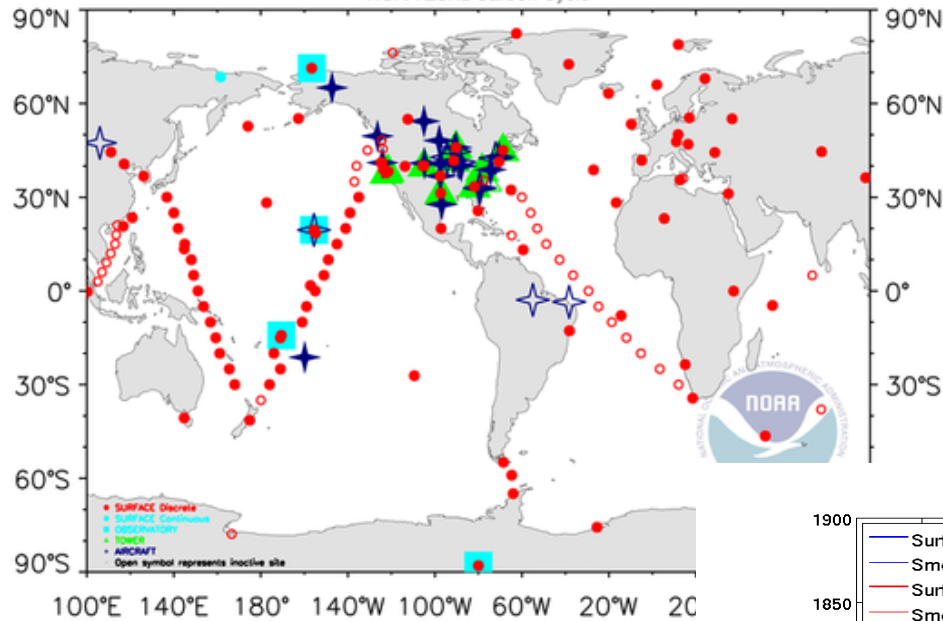
# Ch4 firstguess Optimization



**CH<sub>4</sub> firstguess is a smoothed function of latitude and pressure, and is obtained through a polynomial fitting to observation and model data**

**Model data**

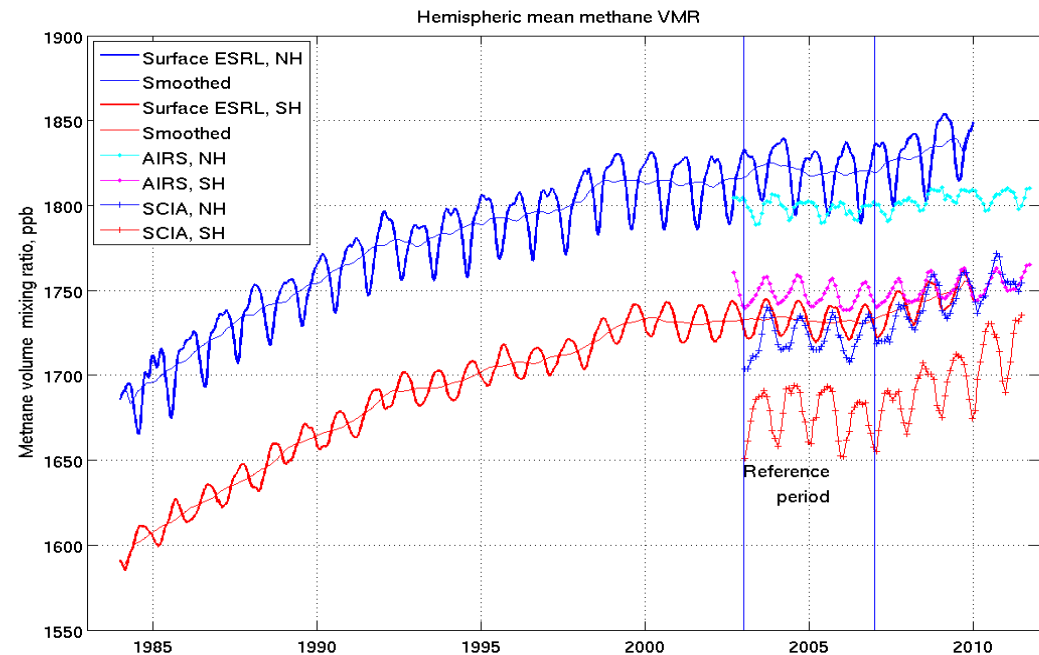
## Cooperative Measurement Programs NOAA ESRL Carbon Cycle



NOAA ESRL Carbon Cycle operates 4 measurement programs. Semi-continuous measurements are made at 4 base from tall towers. Discrete surface and aircraft samples are measured in Boulder, CO. Presently, atmospheric carbon (hydrogen, nitrous oxide, sulfur hexafluoride, the stable isotopes of carbon dioxide and methane, and halocarbon and 1 Contact: Dr. Pieter Tans, NOAA ESRL Carbon Cycle, Boulder, Colorado, (303) 497-6678, pieter.tans@noaa.gov, <http://>

**NOAA/ESRL is the most reliable record of surface CH<sub>4</sub>. Results of CH<sub>4</sub> sampling near the surface at the sites indicated are averaged**

**Courtesy Ed  
Dlugokencky  
(NOAA),  
Christian  
Frankenberg (JPL),**

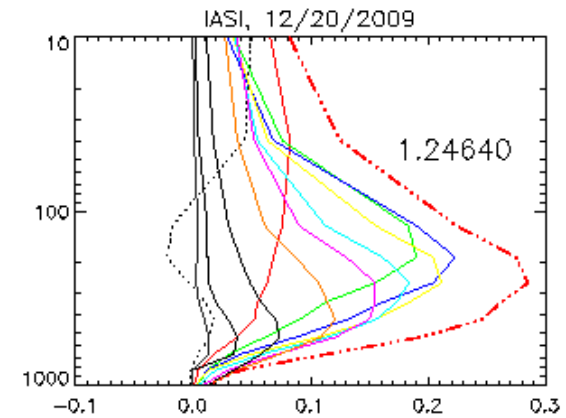
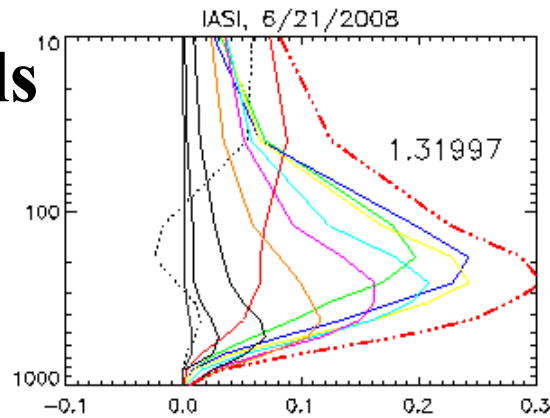




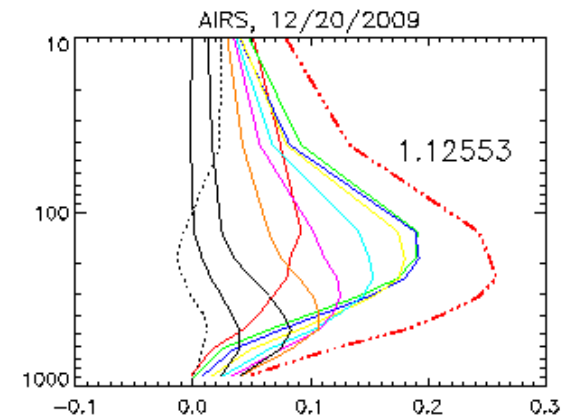
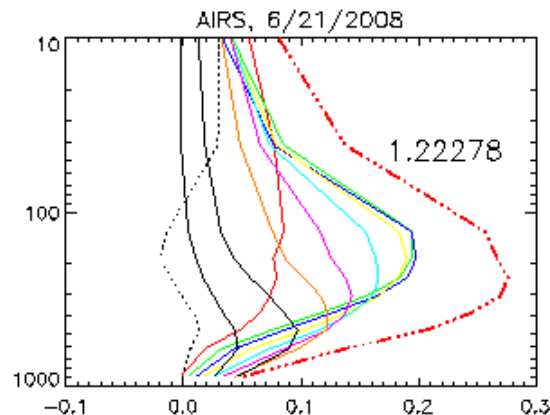
# IASI has more channels, the DOF is slightly higher than AIRS (but it depends on the optimization to the algorithm)

## Averaging Kernels

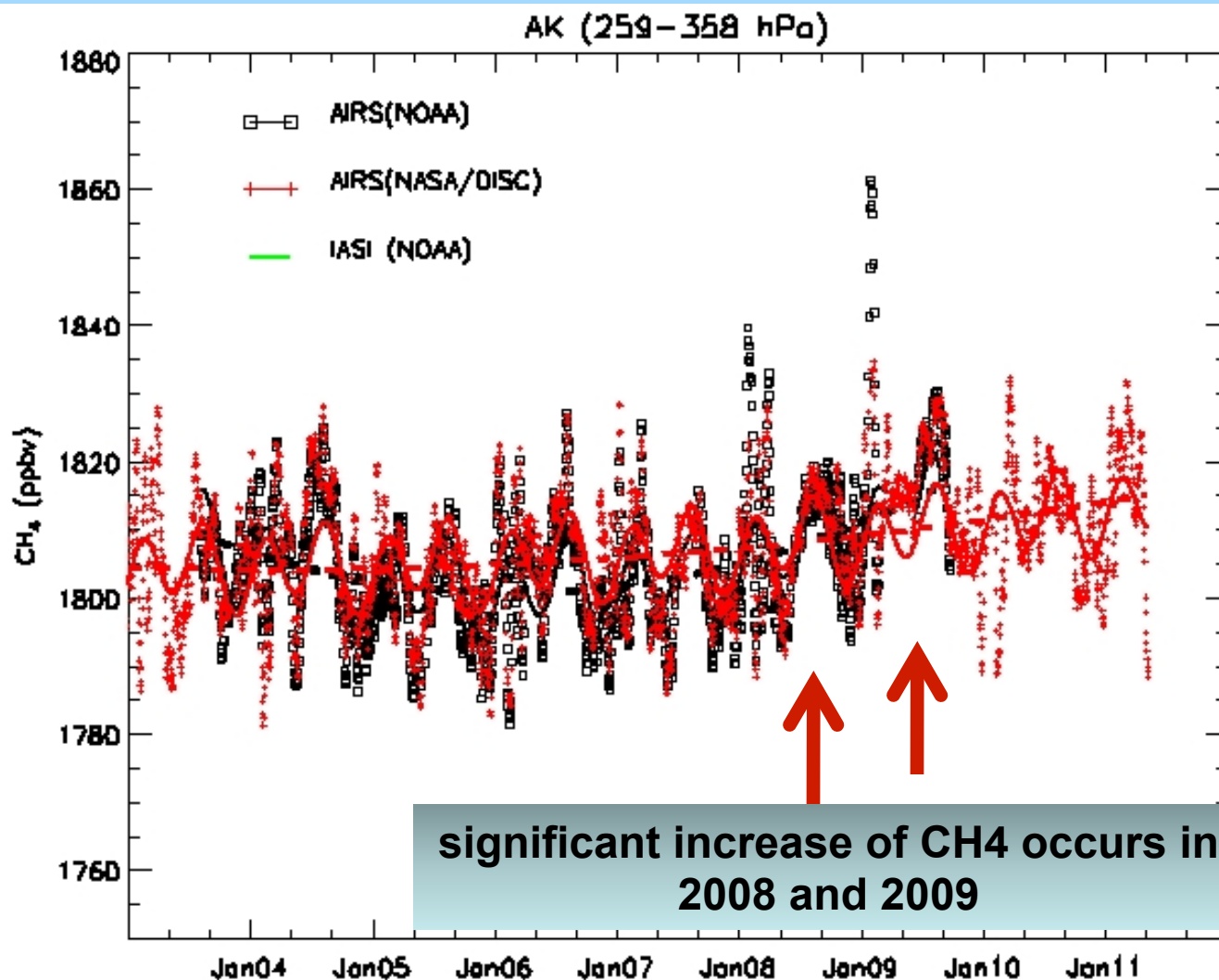
IASI →



AIRS →

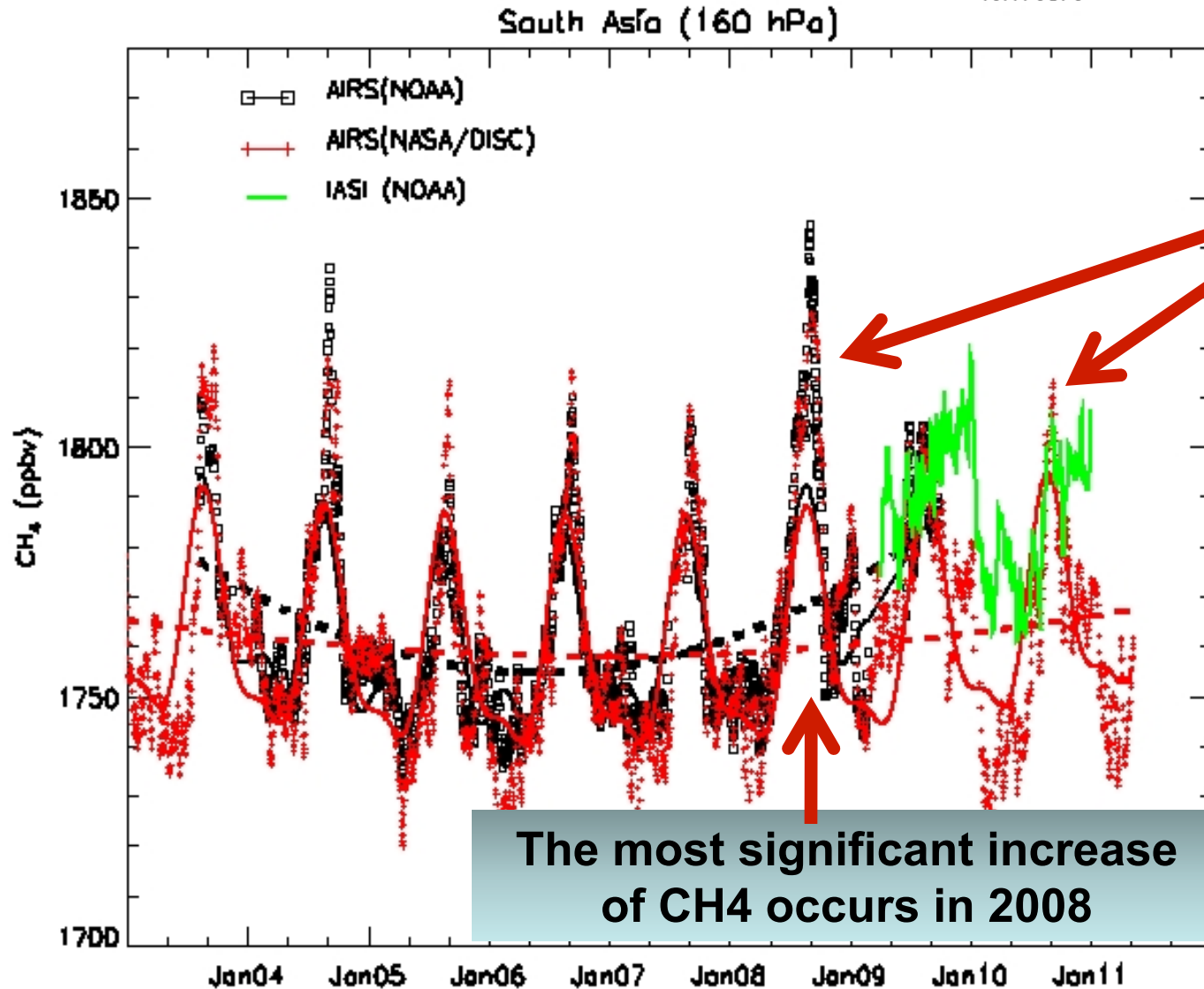


# CH<sub>4</sub> trend over Alaska-Canada - HNH



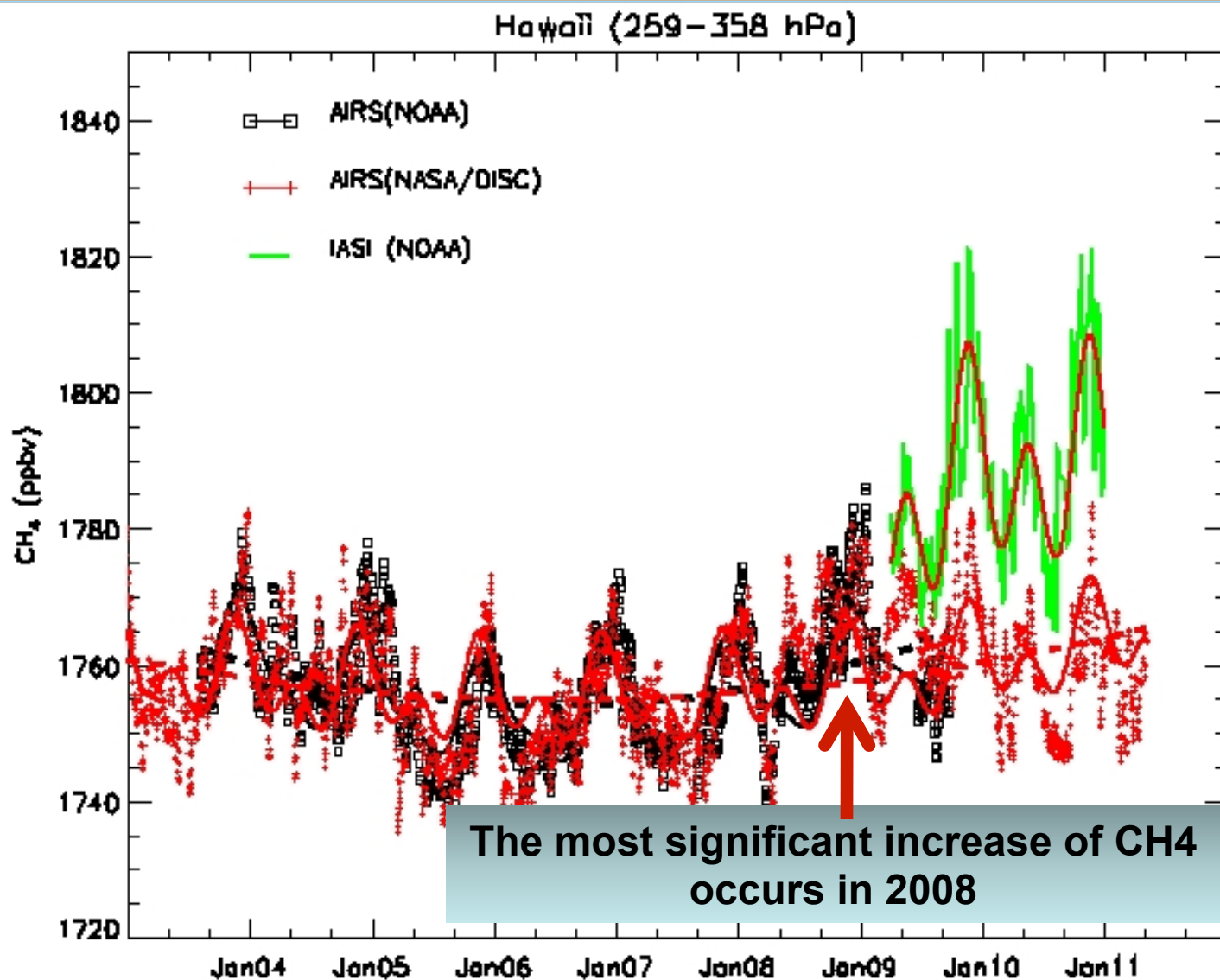


# CH<sub>4</sub> trend over south Asia



The plume has been seen in the past 9 years

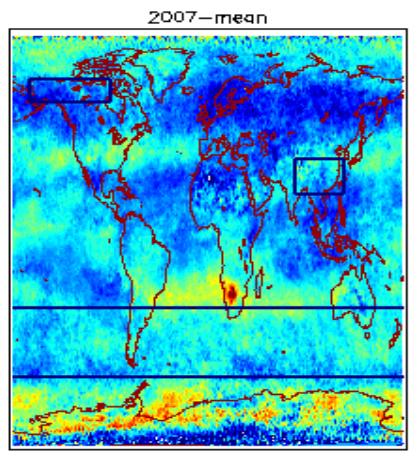
# CH<sub>4</sub> trend over Tropics



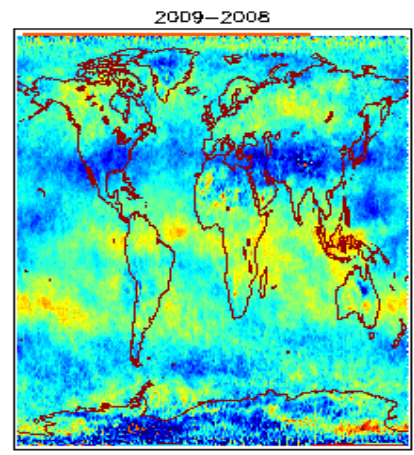


# Annual increase in 2007,08,09

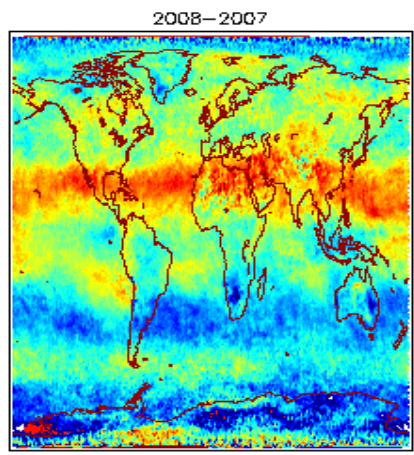
2007-2006



2009-2008



2008-2007



Mean of 2003 to 2006

